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Sakakura

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(54) **SPARK PLUG**

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H01T 13/46 (2006.01)

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CPC ***H01T 13/39*** (2013.01); ***H01T 13/32*** (2013.01); ***H01T 13/467*** (2013.01)

(58) **Field of Classification Search**
USPC .... 123/169 EL
See application file for complete search history.

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(57) **ABSTRACT**

A spark plug including a center electrode, an insulator, a metal shell, a first ground electrode, and a second ground electrode. The center electrode extends in an axial direction. The insulator has an axial hole extending in the axial direction. The center electrode is to be inserted into the axial hole. The metal shell is arranged at an outer periphery of the insulator. The first ground electrode has electrical continuity with the metal shell, and forms a first gap with a front end surface of the center electrode. The second ground electrode has electrical continuity with the metal shell, is sealed to metal shell, extends from the metal shell to a position facing a side surface of the center electrode, and forms an annular second gap between the side surface of the center electrode and an inner peripheral surface of the second ground electrode.

7 Claims, 10 Drawing Sheets

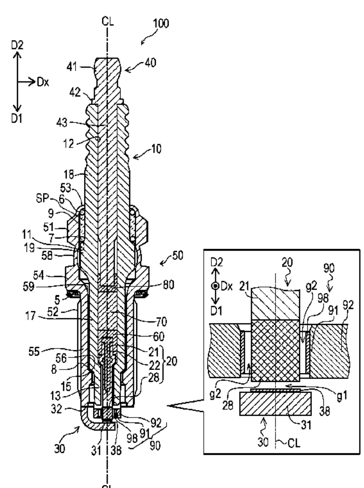
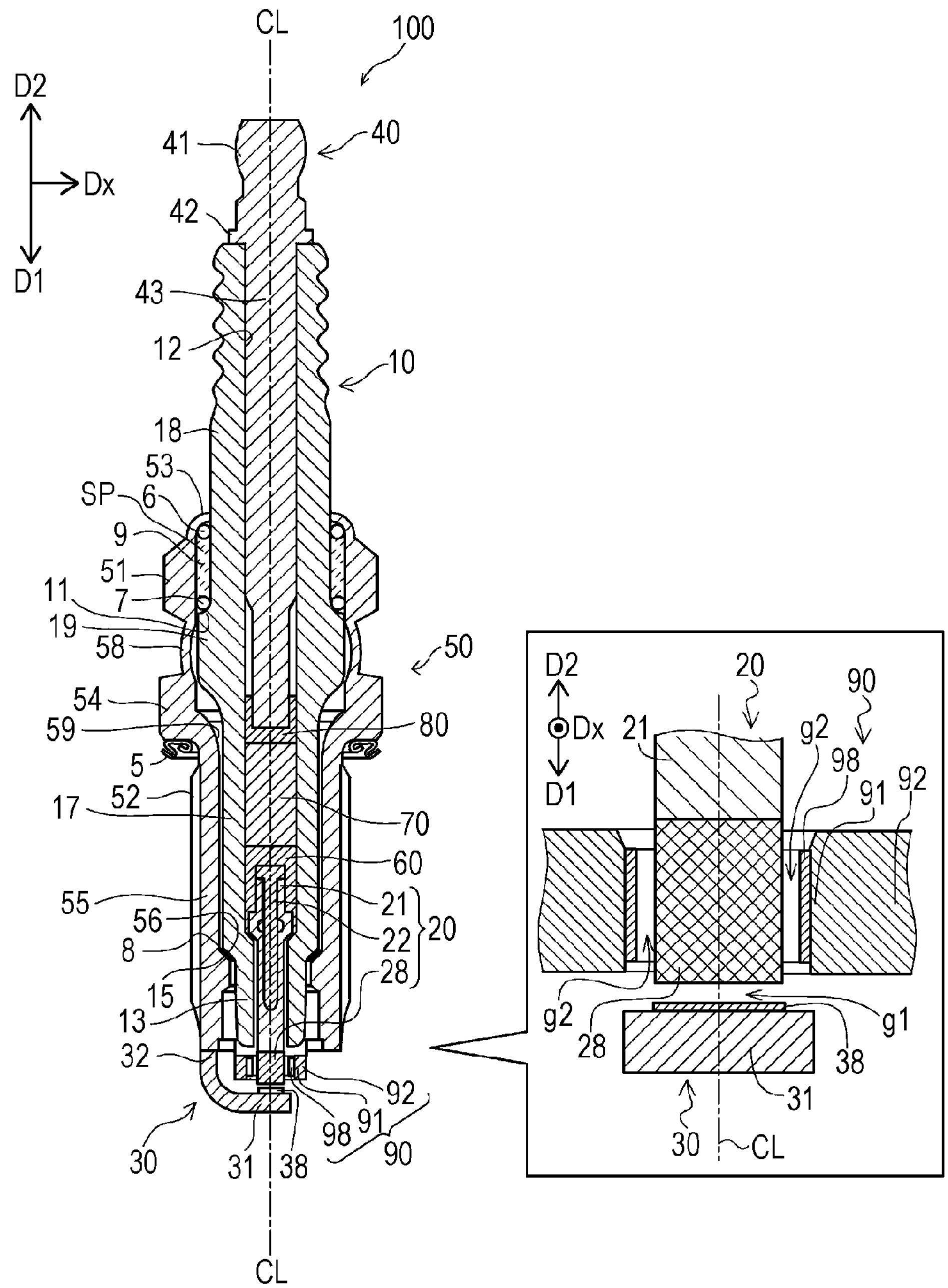


FIG. 1



CL
100
D2
Dx
D1
41
40
42
43
12
10
18
53
SP
6
9
51
7
11
19
58
50
54
59
80
5
52
17
70
60
55
21
56
22
20
8
28
15
13
32
92
98
91
90
30
31
38
CL
D2
Dx
D1
20
21
g2
90
98
91
92
g2
28
g1
38
31
30
CL

FIG. 2A

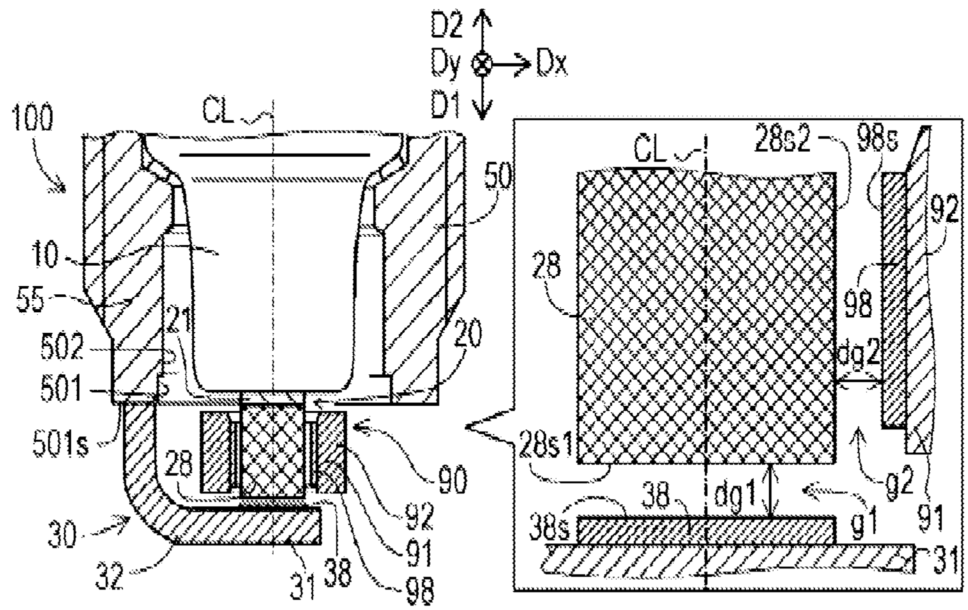

D2
Dy
Dx
D1
100
CL
50
10
55
21
502
20
501
501s
28
90
92
91
30
32
31
38
98
28s2
98s
92
28
98
dg2
28s1
38
dg1
g2
g1
38s
91
31

FIG. 2B

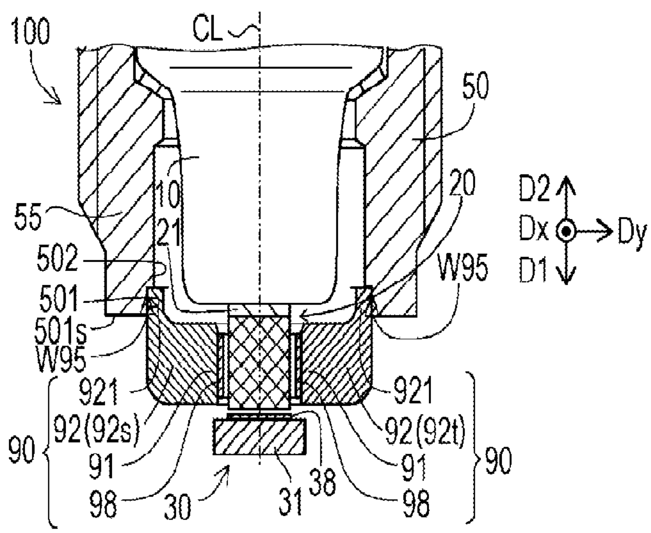
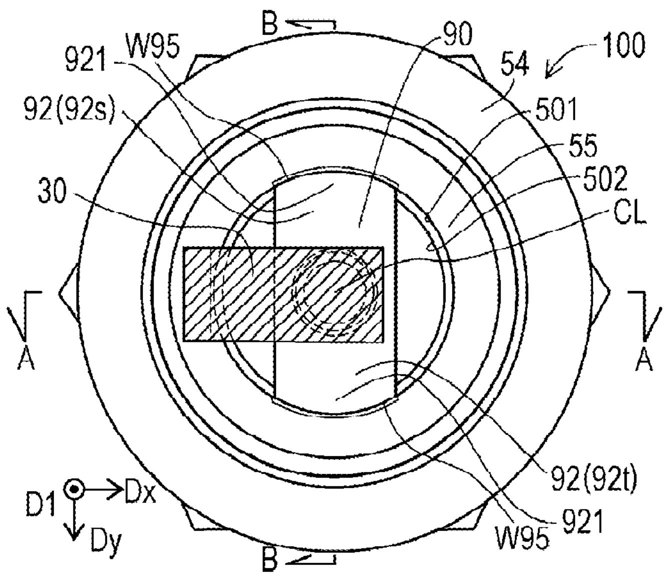
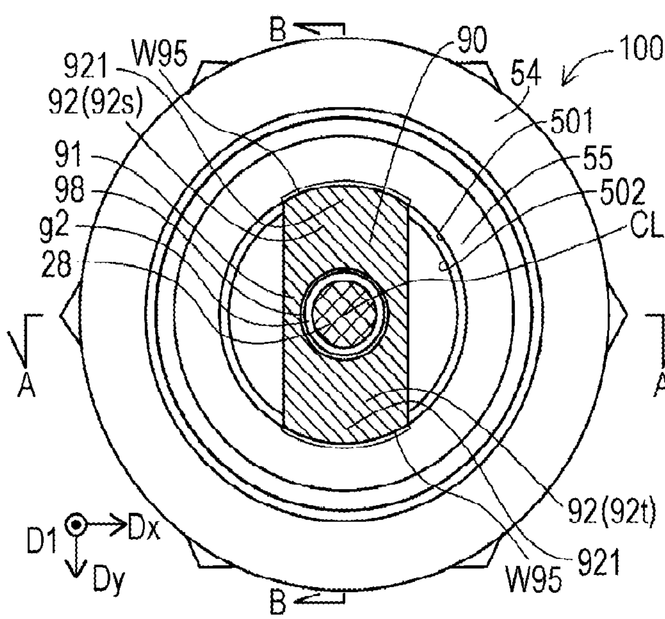

100
CL
50
55
10
20
21
D2
Dx
Dy
D1
502
W95
501
501s
W95
921
921
92(92s)
92(92t)
90
91
91
90
98
30
31
38
98

FIG. 2C



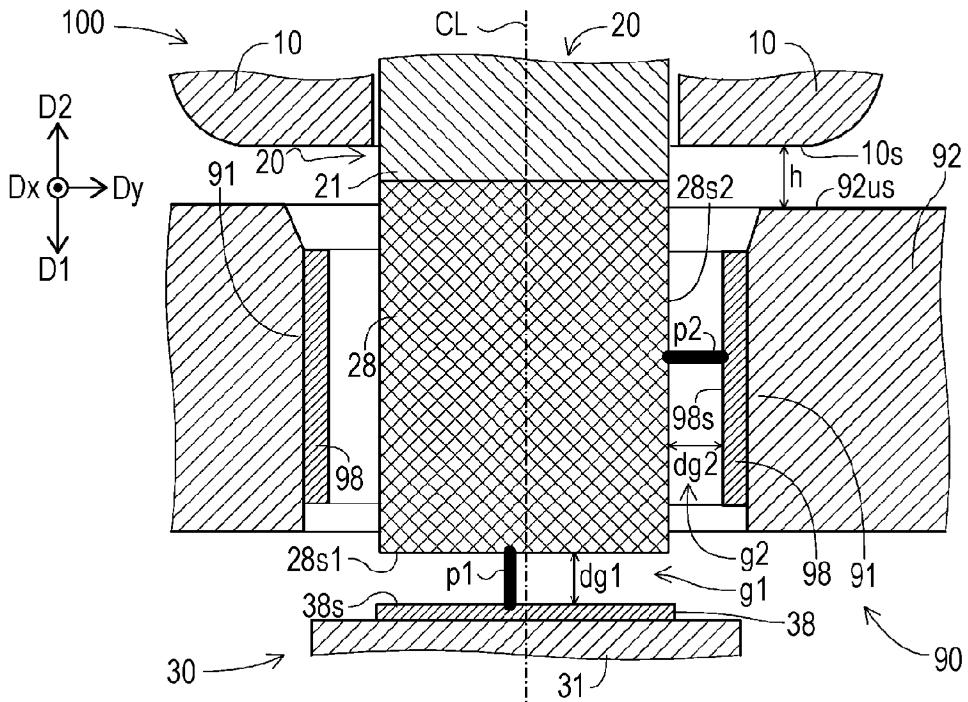
B
90
100
921
W95
54
92(92s)
501
55
30
502
CL
A
A
92(92t)
D1
Dx
Dy
W95
921
B

FIG. 2D



B
90
100
921
W95
54
92(92s)
501
91
55
98
502
g2
CL
28
A
A
92(92t)
D1
Dx
Dy
W95
921
B

FIG. 3A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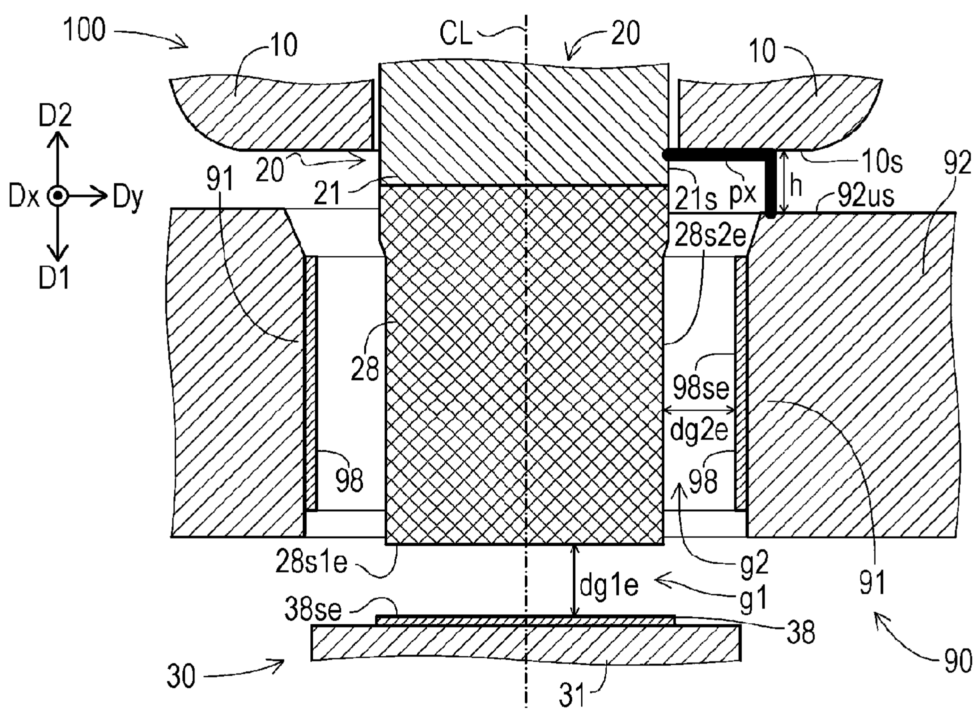
10
CL
20
10
D2
20
21
10s
92
Dx
Dy
91
28s2
h
92us
D1
28
p2
98s
98
dg2
28s1
p1
dg1
g2
g1
98
91
38s
38
30
31
90

FIG. 3B


100
10
CL
20
10
D2
20
21
21s
px
10s
h
92
92us
Dx
Dy
91
28s2e
D1
28
98se
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98
28s1e
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g2
g1
91
38se
38
30
31
90

FIG. 4A

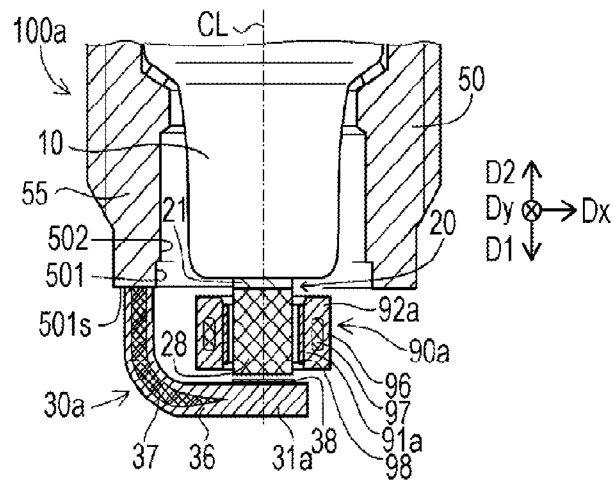

100a
CL
50
10
55
21
502
501
501s
20
92a
90a
28
96
97
91a
98
38
30a
37
36
31a
D2
Dy
Dx
D1

FIG. 4B

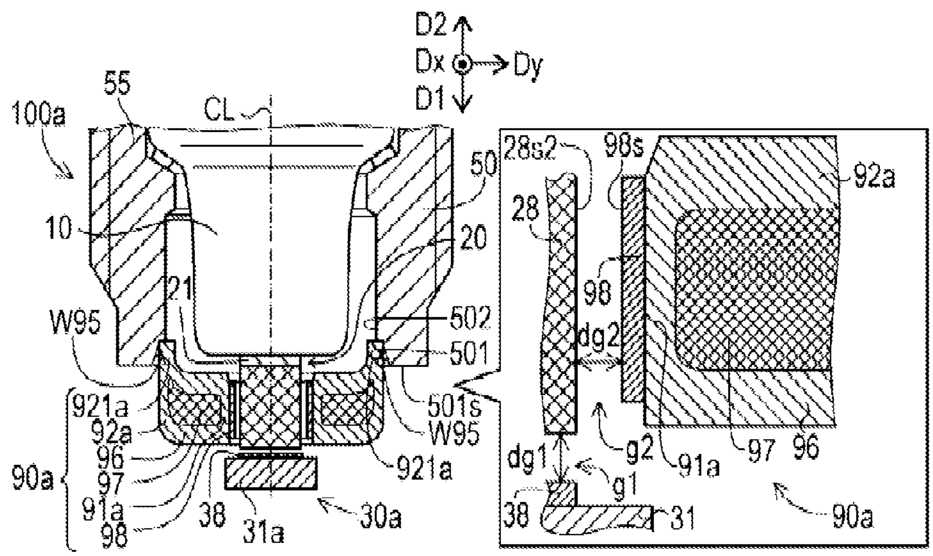

D2
Dx
Dy
D1
55
100a
CL
50
10
20
21
502
501
W95
501s
W95
921a
92a
96
97
91a
98
921a
90a
38
31a
30a
28s2
98s
92a
28
98
dg2
g2
91a
97
96
dg1
g1
38
31
90a

FIG. 4C

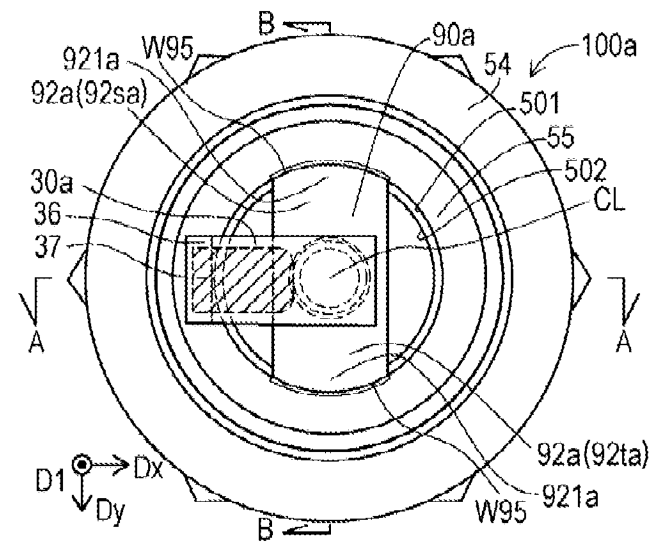

B
90a
100a
921a
W95
54
92a(92sa)
501
55
502
30a
CL
36
37
A
A
92a(92ta)
D1
Dx
921a
Dy
W95
B

FIG. 4D

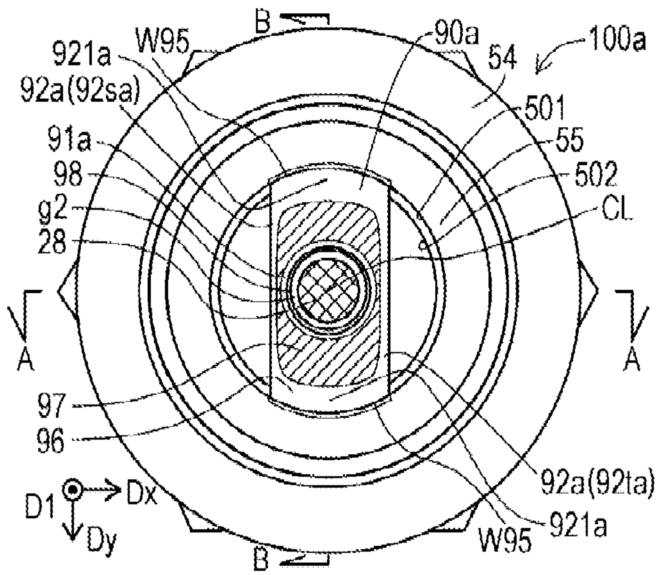

B
90a
100a
921a
W95
54
92a(92sa)
501
91a
55
98
502
g2
CL
28
A
A
97
96
92a(92ta)
D1
Dx
921a
Dy
W95
B

FIG. 5A

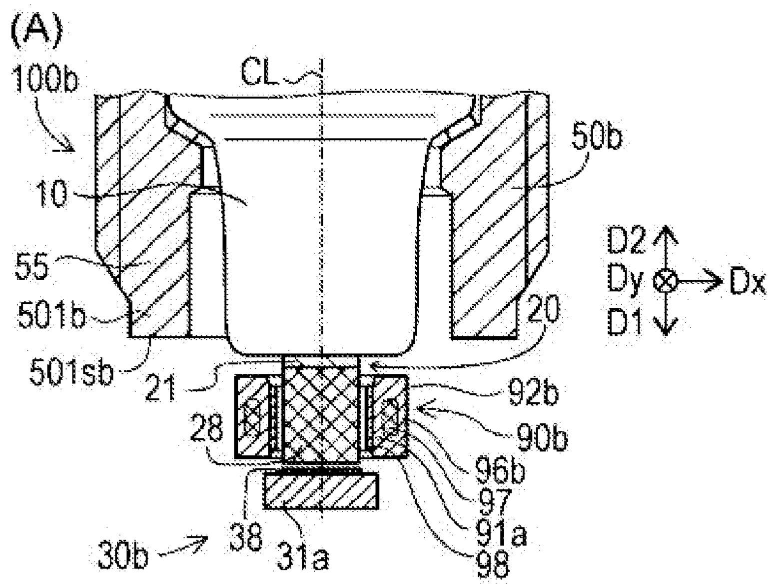

(A)
100b
CL
50b
10
55
501b
501sb
21
20
D2
Dy
Dx
D1
92b
90b
28
96b
97
91a
98
38
31a
30b

FIG. 5B

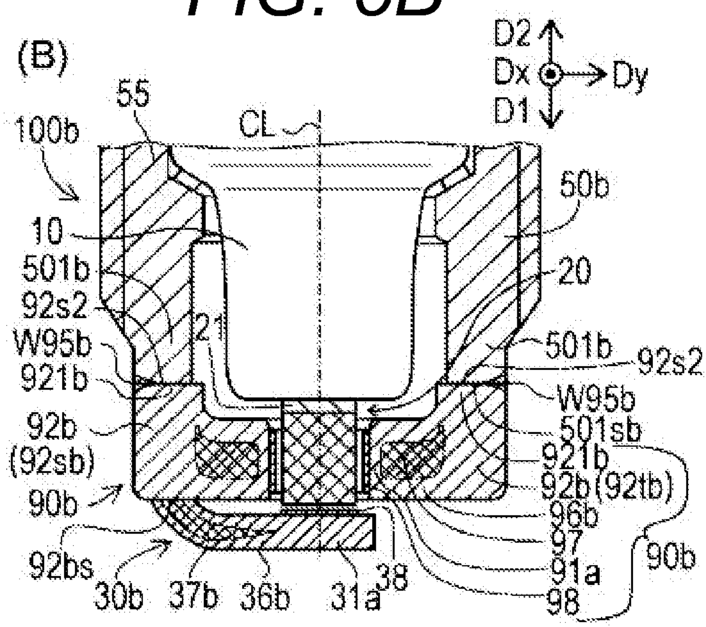
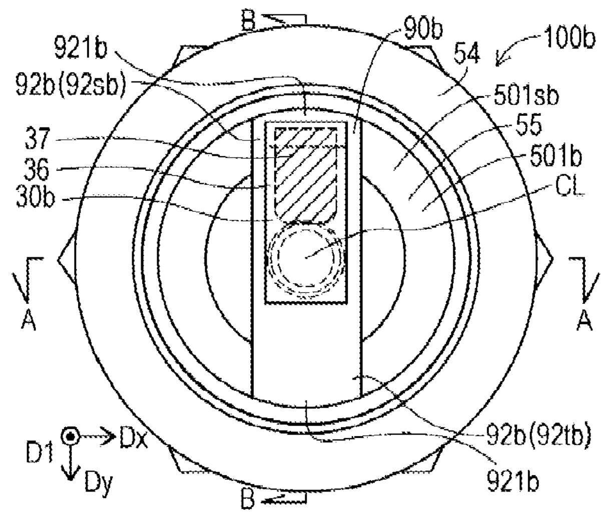
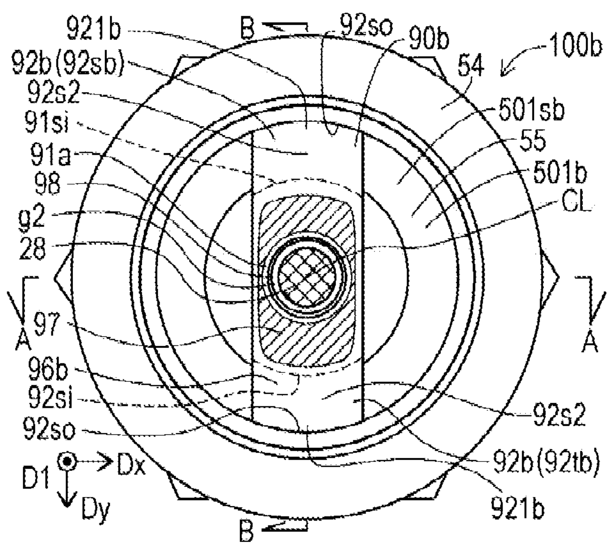

(B)
55
100b
CL
D2
Dx
Dy
D1
50b
10
501b
92s2
20
21
W95b
921b
501b
92s2
W95b
501sb
92b
(92sb)
921b
92b (92tb)
90b
96b
97
91a
98
90b
92bs
30b
37b
36b
31a
38

FIG. 5C



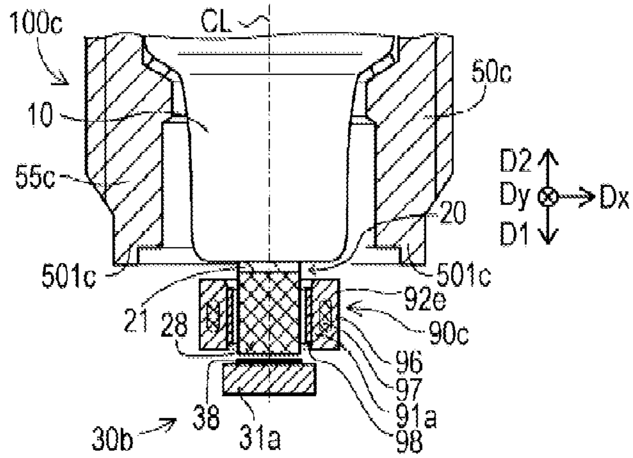
B
921b
92b(92sb)
37
36
30b
90b
54
100b
501sb
55
501b
CL
A
A
D1
Dx
Dy
92b(92tb)
921b
B

FIG. 5D



921b
B
92so
90b
54
100b
92b(92sb)
92s2
91si
91a
98
g2
28
501sb
55
501b
CL
A
97
A
96b
92si
92so
92s2
92b(92tb)
D1
Dx
Dy
921b
B

FIG. 6A


100c
CL
50c
10
55c
D2
Dy
Dx
D1
20
501c
501c
92e
21
28
90c
96
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91a
98
38
31a
30b

FIG. 6B

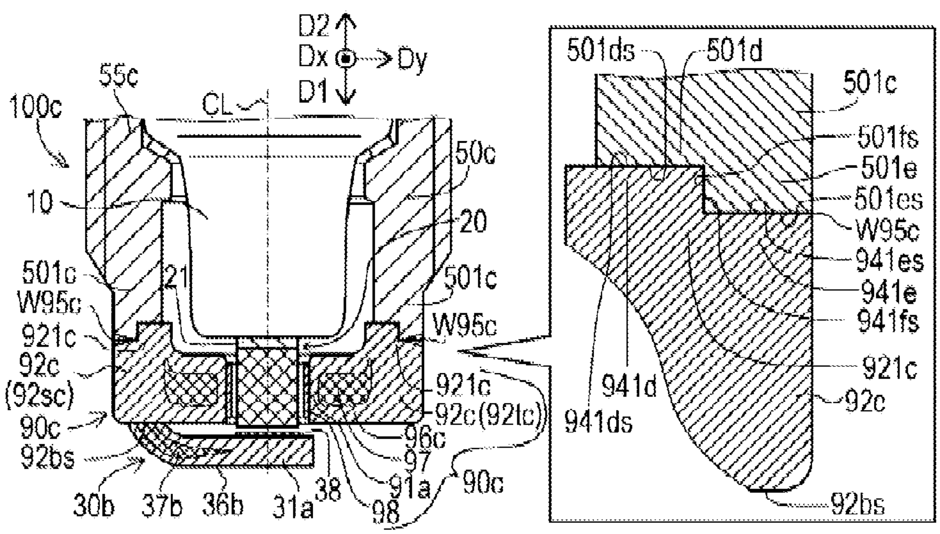
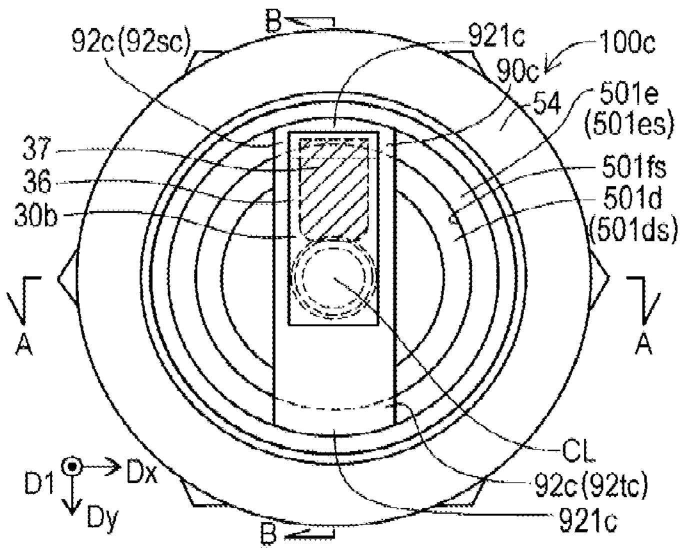
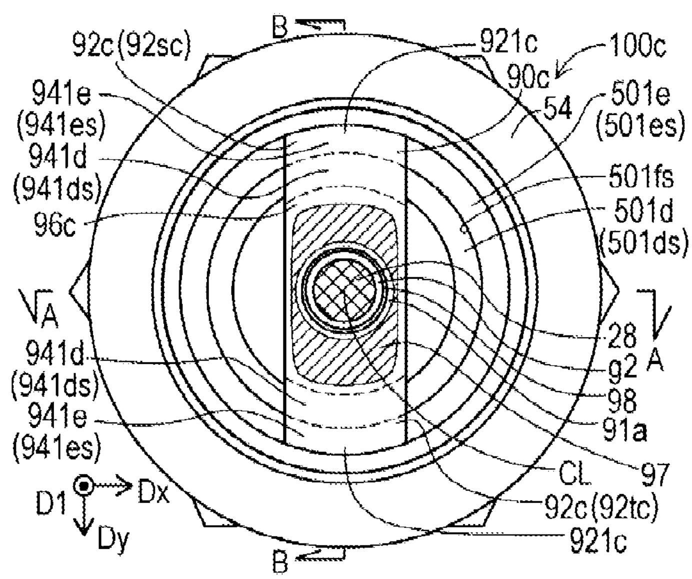

D2
Dx
Dy
D1
55c
CL
100c
50c
10
20
501c
21
501c
W95c
W95c
921c
92c
(92sc)
921c
92c(92tc)
90c
96c
92bs
97
91a
90c
30b
37b
36b
31a
38
98
501ds
501d
501c
501fs
501e
501es
W95c
941es
941e
941fs
921c
941d
92c
941ds
92bs

FIG. 6C



B
92c(92sc)
921c
100c
90c
54
501e
(501es)
37
36
30b
501fs
501d
(501ds)
A
A
CL
D1
Dx
Dy
92c(92tc)
921c
B

FIG. 6D



B
92c(92sc)
921c
100c
90c
54
941e
(941es)
941d
(941ds)
96c
501e
(501es)
501fs
501d
(501ds)
A
28
g2
A
98
941d
(941ds)
941e
(941es)
91a
CL
97
D1
Dx
Dy
92c(92tc)
921c
B

SPARK PLUG

RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/JP14/63470 filed May 21, 2014, which claims the benefit of Japanese Patent Application No. 2013-109156, filed May 23, 2013.

FIELD OF THE INVENTION

The present invention relates to a spark plug.

BACKGROUND OF THE INVENTION

Conventionally, a spark plug is used in an internal combustion engine. The configuration of the spark plug generally includes a center electrode and a ground electrode. The center electrode and the ground electrode form the gap for causing a spark.

Improving the durability of the spark plug suppresses various malfunctions thereby reducing maintenance of the internal combustion engine. In this respect, the durability of the spark plug can be affected by various factors. For example, during the operation of the internal combustion engine, an increase in temperature of the electrode might cause electrode wear. The advance of the electrode wear might not allow the spark plug to provide the intended performance (for example, causes an ignition failure).

An advantage of the present invention is a new technique that improves the durability of the spark plug.

SUMMARY OF THE INVENTION

The present invention has been conceived to solve the above-mentioned problems, and can be realized as the following application examples.

Application Example 1

In accordance with a first aspect of the present invention, there is provided a spark plug having a center electrode, an insulator, a metal shell, a first ground electrode, and a second ground electrode. The center electrode extends in an axial direction. The insulator has an axial hole extending in the axial direction. The center electrode is to be inserted into the axial hole. The metal shell is arranged at an outer periphery of the insulator. The first ground electrode has electrical continuity with the metal shell. The first ground electrode forms a first gap with a front end surface of the center electrode. The second ground electrode has electrical continuity with the metal shell. The second ground electrode is sealed to metal shell. The second ground electrode extends from the metal shell to a position facing a side surface of the center electrode. The second ground electrode forms an annular second gap between the side surface of the center electrode and an inner peripheral surface of the second ground electrode. A proportion of a size of the first gap to a size of the second gap is equal to or more than 0.80 and equal to or less than 1.25.

With this configuration, both the first ground electrode and the second ground electrode are used for discharge. This allows improving the durability of the spark plug.

Application Example 2

In accordance with a second aspect of the present invention, there is provided a spark plug according to the application example 1, wherein the first ground electrode includes a first nickel portion that is a portion formed by nickel or a nickel alloy. The first nickel portion has a nickel content of 90 weight % or more. The second ground electrode includes a second nickel portion that is a portion formed by nickel or a nickel alloy. The second nickel portion has a nickel content of 90 weight % or more.

With this configuration, respective thermal conductivities of the first ground electrode and the second ground electrode are improved. This allows suppressing the wear of the first ground electrode and the second ground electrode due to high temperature.

Application Example 3

In accordance with a third aspect of the present invention, there is provide a spark plug according to the application example 1 or 2, wherein at least one of the first ground electrode and the second ground electrode includes: a surface layer that forms a surface thereof; and a core portion that is formed inside of the surface layer and has a larger thermal conductivity than a thermal conductivity of the surface layer.

With this configuration, the thermal conductivity is improved by the core portion. This allows suppressing the wear of the ground electrode due to high temperature.

Application Example 4

In accordance with a fourth aspect of the present invention, there is provided a spark plug according to the application example 3, wherein the first ground electrode is sealed to the second ground electrode.

With this configuration, the temperature of the first ground electrode is likely to increase compared with the case where the first ground electrode is sealed directly to the metal shell. However, the thermal conductivity is improved by the core portion. This allows suppressing the wear of the ground electrode due to high temperature.

Application Example 5

In accordance with a fifth aspect of the present invention, there is provided a spark plug according to any one of the application examples 1 to 4, wherein a shortest distance between a surface of the second ground electrode and a surface of the insulator is twice or more as large as a maximum value between the size of the first gap and the size of the second gap.

This configuration allows suppressing occurrence of discharge along the surface of the insulator even in the case where the first gap and the second gap are large due to the wear of the ground electrode. Accordingly, the durability of the spark plug can be improved.

Application Example 6

In accordance with a sixth aspect of the present invention, there is provided a spark plug according to any one of the application examples 1 to 5, wherein the first ground electrode includes a first noble metal portion that is formed by a noble metal or a noble metal alloy in a position forming the first gap. The second ground electrode includes a second noble metal portion that is formed by a noble metal or a noble metal alloy in a position forming the second gap. In the center electrode, at least a first portion and a second portion are formed by a noble metal or a noble metal alloy. The first portion forms the first gap with the first noble metal portion. The second portion forms the second gap with the second noble metal portion.

This configuration allows suppressing the wear of each of the center electrode, the first ground electrode, and the second ground electrode.

Application Example 7

In accordance with a seventh aspect of the present invention, there is provided a spark plug according to the application example 6, wherein the noble metal or the noble metal alloy is iridium or an iridium alloy.

This configuration allows appropriately suppressing the wear of each of the center electrode, the first ground electrode, and the second ground electrode.

Here, the present invention can be realized by various forms, for example, can be realized in a form of a spark plug, an internal combustion engine on which the spark plug is mounted or similar form.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of a spark plug **100** of a first embodiment.

FIGS. **2**A to **2**D are schematic diagrams showing the configurations of electrodes **20**, **30**, and **90** of the spark plug **100**.

FIGS. **3**A and **3**B are explanatory views of creeping discharges.

FIGS. **4**A to **4**D are schematic diagrams showing a second embodiment of the spark plug.

FIGS. **5**A to **5**D are schematic diagrams showing a third embodiment of the spark plug.

FIGS. **6**A to **6**D are schematic diagrams showing a fourth embodiment of the spark plug.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A. First Embodiment

A1. Configuration of Spark Plug

FIG. **1** is a sectional view of a spark plug **100** of a first embodiment. The line CL shown in the drawing denotes the central axis of the spark plug **100**. Hereinafter, the central axis CL is also referred to as an "axial line CL" and the direction parallel to the central axis CL is also referred to as an "axial direction." The radial direction of the circle around the central axis CL is also referred to simply as a "radial direction" and the direction of the circumference of the circle around the central axis CL is also referred to as a "circumferential direction." In the drawings, the first direction D**1** and the second direction D**2** are parallel to the axial line CL. The second direction D**2** is the direction opposite to the first direction D**1**. As describe later, a center electrode **20**, a first ground electrode **30**, and a second ground electrode **90**, which form a spark gap (also referred to simply as a "gap"), form the end portion on the first direction D**1** side of the spark plug **100**. Hereinafter, the first direction D**1** side is also referred to as a "front end side," and the second direction D**2** side is also referred to as a "rear end side."

The spark plug **100** includes a ceramic insulator **10**, the center electrode **20**, the first ground electrode **30**, the second ground electrode **90**, a terminal metal fitting **40**, a metal shell **50**, a conductive seal **60**, a resistor element **70**, a conductive seal **80**, a front-end-side packing **8**, a talc **9** as one example of a buffer, a first rear-end-side packing **6**, and a second rear-end-side packing **7**. The right side in the drawing shows an expansion (i.e., enlarged) figure of the cross section of the portions forming gaps g**1** and g**2** described later in the center electrode **20**, the first ground electrode **30**, and the second ground electrode **90** viewed from another direction.

The ceramic insulator **10** is an approximately cylindrically-shaped member with a through hole **12** (an axial hole). The through hole **12** extends along the central axis CL so as to pass through the ceramic insulator **10**. The ceramic insulator **10** is formed by sintering alumina (another insulating material can also be adopted). The ceramic insulator **10** includes a nose portion **13**, a first outer-diameter contracted portion **15**, a front-end-side trunk portion **17**, a flange portion **19**, a second outer-diameter contracted portion **11**, and a rear-end-side trunk portion **18** that are arranged from the front end side toward the rear end side in this order.

The flange portion **19** is the portion positioned approximately in the center of the axial direction of the ceramic insulator **10**, and is the maximum outer diameter portion of the ceramic insulator **10**. On the front end side of the flange portion **19**, the front-end-side trunk portion **17** is disposed. On the front end side of the front-end-side trunk portion **17**, the first outer-diameter contracted portion **15** is disposed. The outer diameter of the first outer-diameter contracted portion **15** gradually decreases from the rear end side toward the front end side. On the front end side of the first outer-diameter contracted portion **15**, the nose portion **13** is disposed. In the state where the spark plug **100** is installed on an internal combustion engine (not shown), the nose portion **13** is exposed to a combustion chamber.

On the rear end side of the flange portion **19**, the second outer-diameter contracted portion **11** is disposed. The outer diameter of the second outer-diameter contracted portion **11** gradually decreases from the front end side toward the rear end side. On the rear end side of the second outer-diameter contracted portion **11**, the rear-end-side trunk portion **18** is disposed.

Into the front end side of the through hole **12** of the ceramic insulator **10**, the center electrode **20** is inserted. The center electrode **20** is a rod-shaped member that extends along the central axis CL. The center electrode **20** includes an electrode base material **21**, a core material **22**, and a column-shaped tip **28**. The core material **22** is buried inside of the electrode base material **21**. The tip **28** is sealed to the front end side of the electrode base material **21**, and has the center on the central axis CL. The rear end portion of the core material **22** is exposed from the electrode base material **21** so as to form the rear end portion of the center electrode **20**. The other portion of the core material **22** is coated with the electrode base material **21**. However, the entire core material **22** may be covered with the electrode base material **21**. The electrode base material **21** is formed by using, for example, an alloy containing nickel. The core material **22** is formed of, for example, an alloy containing copper. The tip **28** is formed of an alloy containing iridium (however, another conductive material (for example, a metallic material) can also be adopted). The tip **28** is sealed to the electrode base material **21** by, for example, laser beam welding. A part of the rear end side of the center electrode **20** is arranged within the through hole **12** of the ceramic insulator **10**. A part of the front end side of the center electrode **20** is exposed on the front end side of the ceramic insulator **10**.

Into the rear end side of the through hole **12** of the ceramic insulator **10**, the terminal metal fitting **40** is inserted. The terminal metal fitting **40** is a rod-shaped member that extends along the central axis CL. The terminal metal fitting **40** is formed using low-carbon steel (however, another conductive material (for example, a metallic material) can also be adopted). The terminal metal fitting **40** includes a flange portion **42**, a plug cap installation portion **41**, and a nose portion **43**. The plug cap installation portion **41** forms the portion on the rear end side with respect to the flange portion **42**. The nose portion **43** forms the portion on the front end side with respect to the flange portion **42**. The plug cap installation portion **41** is exposed on the rear end side of the ceramic insulator **10**. The nose portion **43** is inserted into the through hole **12** of the ceramic insulator **10**.

In the through hole **12** of the ceramic insulator **10**, the resistor element **70** is arranged between the terminal metal fitting **40** and the center electrode **20**. The resistor element **70** reduces the radio wave noise during the occurrence of the spark. The resistor element **70** is formed by the composition containing glass particles such as B_2O_3—SiO_2-based glass particles, ceramic particles such as ZrO_2 ceramic particles, and a conductive material such as carbon particles and metal.

In the through hole **12**, the clearance between the resistor element **70** and the center electrode **20** is filled with the conductive seal **60**. The clearance between the resistor element **70** and the terminal metal fitting **40** is filled with the conductive seal **80**. As a result, the center electrode **20** and the terminal metal fitting **40** electrically connect to each other via the resistor element **70** and the conductive seals **60** and **80**. The conductive seal is formed using, for example, various glass particles described above and metal particles (such as Cu and Fe).

The metal shell **50** is a cylindrically-shaped metal shell for securing the spark plug **100** to an engine head (not shown) of the internal combustion engine. The metal shell **50** is formed using a low-carbon steel material (or another conductive material (for example, a metallic material) can also be adopted). In the metal shell **50**, a through hole **59** is formed. The through hole **59** passes through along the central axis CL. The ceramic insulator **10** is inserted into the through hole **59** of the metal shell **50**. The metal shell **50** is secured to the outer periphery of the ceramic insulator **10**. The front end of the ceramic insulator **10** is exposed from the front end of the metal shell **50**. The rear end of the ceramic insulator **10** is exposed from the rear end of the metal shell **50**.

The metal shell **50** includes a body **55**, a seal portion **54**, a deformed portion **58**, a tool engagement portion **51**, and a crimp portion **53** that are arranged from the front end side toward the rear end side in this order. The shape of the seal portion **54** is approximately cylindrically shaped. On the front end side of the seal portion **54**, the body **55** is disposed. The outer diameter of the body **55** is smaller than the outer diameter of the seal portion **54**. On the outer peripheral surface of the body **55**, a screw portion **52** is formed to be threadably mounted on the mounting hole of the internal combustion engine. Between the seal portion **54** and the screw portion **52**, an annular gasket **5** is fitted by insertion. The gasket **5** is formed by folding a metal plate.

The body **55** of the metal shell **50** includes an inner-diameter contracted portion **56**. The inner-diameter contracted portion **56** is arranged on the front end side with respect to the flange portion **19** of the ceramic insulator **10**. The internal diameter of the inner-diameter contracted portion **56** gradually decreases from the rear end side toward the front end side. Between the inner-diameter contracted portion **56** of the metal shell **50** and the first outer-diameter contracted portion **15** of the ceramic insulator **10**, the front-end-side packing **8** is sandwiched. The front-end-side packing **8** is made of steel, and is an O-shaped ring. Here, another material (for example, a metallic material such as copper) can also be adopted.

On the rear end side of the seal portion **54**, the deformed portion **58** is disposed. The deformed portion **58** has a wall thickness thinner than that of the seal portion **54**. The deformed portion **58** is deformed such that the center portion projects toward the outside in the radial direction (the direction away from the central axis CL). On the rear end side of the deformed portion **58**, the tool engagement portion **51** is disposed. The shape of the tool engagement portion **51** is a shape (for example, a hexagonal prism) with which a spark plug wrench is engaged. On the rear end side of the tool engagement portion **51**, the crimp portion **53** is disposed. The crimp portion **53** has a wall thickness thinner than that of the tool engagement portion **51**. The crimp portion **53** is arranged on the rear end side with respect to the second outer-diameter contracted portion **11** of the ceramic insulator **10** so as to form the rear end of the metal shell **50**. The crimp portion **53** is flexed to radially inside.

Between the inner peripheral surface of the portion on the rear end side of the metal shell **50** and the outer peripheral surface of the ceramic insulator **10**, an annular space SP is formed. This space SP is a space formed by the inner peripheral surface of the metal shell **50** and the outer peripheral surface of the ceramic insulator **10** at a position between the crimp portion **53** and the second outer-diameter contracted portion **11**. On the rear end side within this space SP, the first rear-end-side packing **6** is arranged. On the front end side within this space SP, the second rear-end-side packing **7** is arranged. In this embodiment, these rear-end-side packings **6** and **7** are C-shaped rings made of steel (another material can also be adopted). Between the two rear-end-side packings **6** and **7** within the space SP, the powders of the talc **9** are filled up.

The crimp portion **53** is crimped so as to be folded to the inside. Accordingly, the ceramic insulator **10** is pressed to the front end side within the metal shell **50** via the packings **6** and **7** and the talc **9**. Thus, the front-end-side packing **8** is pressed between the first outer-diameter contracted portion **15** and inner-diameter contracted portion **56**. The front-end-side packing **8** seals between the metal shell **50** and the ceramic insulator **10**. The above-described configuration suppresses the gas inside of the combustion chamber of the internal combustion engine to leak to the outside through between the metal shell **50** and the ceramic insulator **10**.

The first ground electrode **30** includes a base material **32** and a tip **38**. The base material **32** is sealed to the front end of the metal shell **50**. The tip **38** is sealed to a front end portion **31** of the base material **32**. The base material **32** extends from the end sealed to the metal shell **50** toward the first direction D**1**, folded by approximately 90 degrees toward the central axis CL. The front end portion **31** is arranged on the front end side of the center electrode **20**. The X direction Dx in the drawings is the direction vertical to the central axis CL from the sealed portion between the metal shell **50** and the base material **32** toward the central axis CL. The partial expansion figure in FIG. **1** shows the cross section that includes the central axis CL and is vertical to the X direction Dx. The tip **38** is sealed by, for example, laser beam welding on the base material **32** in the position facing the front end surface of the tip **28** of the center electrode **20**, specifically, on the surface on the second direction D**2** side of the front end portion **31**. The shape of the tip **38** is a circular plate shape having the center on the central axis CL. The base material **32** is formed using a nickel alloy containing nickel of 90 weight % or more. The tip **38** is formed using an alloy containing iridium. The surface on the second direction D**2** side of the tip **38** of the first ground electrode **30** and the surface (front end surface) on the first direction D**1** side of the tip **28** of the center electrode **20** form a first gap g**1**.

The second ground electrode **90** includes a supporting portion **92** and a cylindrically-shaped tip **98** (also referred to as the "cylindrical tip **98**"). The supporting portion **92** includes a hole forming portion **91** that forms a column-shaped through hole having the center on the central axis CL, and is sealed to the front end portion of the metal shell **50**. The tip **98** is sealed to the inner peripheral surface of the hole forming portion **91**, and has the center on the central axis CL. The cylindrical tip **98** is sealed to the inner peripheral surface of the hole forming portion **91** by, for example, brazing. The supporting portion **92** is sealed to the inner peripheral surface of the front end portion of the metal shell **50** (details will be described later). The supporting portion **92** is formed using a nickel alloy that contains nickel of 90 weight % or more. The cylindrical tip **98** is formed using an alloy that contains iridium. The inner peripheral surface of the cylindrical tip **98** of the second ground electrode **90** and the outer peripheral surface of the tip **28** of the center electrode **20** form an annular second gap g**2**.

A2. Configuration of Electrode

FIGS. **2**A to **2**D are schematic diagrams showing the configurations of the electrodes **20**, **30**, and **90** of the spark plug **100**. FIG. **2**A shows a partial sectional view (a sectional view including the central axis CL) parallel to the X direction Dx on the first direction D**1** side of the spark plug **100**. FIG. **2**B shows a sectional view (a sectional view including the central axis CL) of the same portion vertical to the X direction Dx. FIG. **2**C shows a schematic diagram of the spark plug **100** observed from the first direction D**1** side toward the second direction D**2**. FIG. **2**D shows a schematic diagram of the remaining portion after the first ground electrode **30** is deleted from the schematic diagram of FIG. **2**C. In the drawings, the two directions Dx and Dy perpendicular to the central axis CL are shown in addition to the first direction D**1** and the second direction D**2**. The Y direction Dy is a direction perpendicular to the X direction Dx. FIG. **2**A is the cross section taken along the line A-A of FIG. **2**C, and is the cross section that divides the base material **32** of the first ground electrode **30** in half. FIG. **2**B is the cross section taken along the line B-B of FIG. **2**C.

Here, FIG. **2**A and FIG. **2**B show the appearances of the ceramic insulator **10** observed facing the direction vertical to the cross section. Here, the right side in FIG. **2**A shows an expansion figure of the portion including the tip **28**. In FIG. **2**C, the first ground electrode **30** is hatched. In FIG. **2**D, the tip **28** and the second ground electrode **90** are hatched.

As shown in FIG. **2**A and FIG. **2**D, the cylindrical tip **98** of the second ground electrode **90** surrounds the peripheral area of the tip **28** of the center electrode **20** on the outside in the radial direction over the whole circumference. The annular second gap g**2** is formed by an inner peripheral surface **98***s* (the surface on the inside of the radial direction in FIG. **2**A) of the cylindrical tip **98** and an outer peripheral surface **28***s***2** (the surface on the outside in the radial direction) of the tip **28** of the center electrode **20**.

As shown in FIG. **2**B and FIG. **2**D, the supporting portion **92** of the second ground electrode **90** is a plate-shaped member that extends from the −Dy direction side to the +Dy direction side of the central axis CL along the Y direction Dy. Here, the +Dy direction denotes the Y direction Dy, and the −Dy direction denotes the direction opposite to the Y direction Dy. In the drawings, two connecting portions **92***s* and **92***t* forming the supporting portion **92** are shown. The first connecting portion **92***s* is the portion on the −Dy direction side with respect to the central axis CL in the supporting portion **92**. On the outside in the radial direction in the first connecting portion **92***s*, an end portion **921** is sealed to the metal shell **50** on the −Dy direction side with respect to the central axis CL. The second connecting portion **92***t* is the portion on the +Dy direction side with respect to the central axis CL in the supporting portion **92**. On the outside in the radial direction in the second connecting portion **92***t*, an end portion **921** is sealed to the metal shell **50** on the +Dy direction side with respect to the central axis CL. The respective shapes of the first connecting portion **92***s* and the second connecting portion **92***t* are mutually the same.

As shown in FIG. **2**B, the supporting portion **92** (specifically, the connecting portions **92***s* and **92***t*) extends from the connecting portion (that is, the hole forming portion **91**) with the cylindrical tip **98** toward the outside in the radial direction, is bent toward the second direction D**2**, extends toward the second direction D**2** side, and reaches the end portion **921**. The outer peripheral surface of the end portion **921** is sealed to the inner peripheral surface of the metal shell **50** by welding. For example, a boundary portion W**95** between the end portion **921** of the supporting portion **92** and the metal shell **50** is welded by laser beam welding from the first direction D**1** side. Accordingly, the second ground electrode **90** has electrical continuity with the metal shell **50**.

As shown in FIG. **2**A, in the end portion on the first direction D**1** side, the metal shell **50** (specifically, the body **55**), a large internal diameter portion **501** is formed. The large internal diameter portion **501** has a relatively large internal diameter. On the second direction D**2** side of the large internal diameter portion **501**, a small internal diameter portion **502** is formed. The small internal diameter portion **502** has an internal diameter smaller than that of the large internal diameter portion **501**. In the boundary portion between the large internal diameter portion **501** and the small internal diameter portion **502**, a level difference (i.e., annular surface) is formed. At the level difference, the internal diameter changes in a stepped pattern. The second ground electrode **90** is fitted to this large internal diameter portion **501** from the first direction D**1** side toward the second direction D**2**.

As shown in FIG. **2**B and FIG. **2**D, the second ground electrode **90** is constituted such that the two end portions **921** of the supporting portion **92** are brought into contact with the inner peripheral surface of the large internal diameter portion **501** of the metal shell **50**. Specifically, in the case of observation facing the direction parallel to the central axis CL as shown in FIG. **2**D, the shapes of the edges on the outer periphery side of the two end portions **921** are arc shapes having diameters that is larger than the internal diameter of the small internal diameter portion **502** and is slightly smaller than the internal diameter of the large internal diameter portion **501**. Accordingly, in the case where the second ground electrode **90** is fitted to the large internal diameter portion **501**, the surfaces on the second direction D**2** side of the two end portions **921** of the supporting portion **92** are brought into contact with the level difference (annular surface) between the large internal diameter portion **501** and the small internal diameter portion **502**. Accordingly, this inhibits the second ground electrode **90** from getting into the small internal diameter portion **502**, thus suppressing the displacement of the second ground electrode **90** in the first direction D**1** with respect to the metal shell **50**. Additionally, the two end portions **921** of the supporting portion **92** are brought into contact with the inner peripheral surface of the large internal diameter portion **501**. This suppresses the displacement (the displacement of the second ground electrode **90** with respect to the metal shell **50**) in the direction perpendicular to the central axis CL. As a result, a size dg**2** (also referred to as the "second gap size dg**2**") of the second gap g**2** is approximately constant over the whole circumference on the outer peripheral surface **28**_s_**2** of the tip **28** of the center electrode **20**.

As shown in FIG. **2**A, the first ground electrode **30** is welded to a front end surface **501**_s_ of the metal shell **50** (for example, by laser beam welding). Accordingly, the first ground electrode **30** has electrical continuity with the metal shell **50**. As shown in FIG. **2**C, the first ground electrode **30** is arranged to extend in the X direction Dx vertical to the direction (that is, the Y direction Dy) extending the supporting portion **92** of the second ground electrode **90**. As shown in the expansion figure in FIG. **2**A, a front end surface **28**_s_**1** of the tip **28** of the center electrode **20** is a planar surface perpendicular to the central axis CL. Additionally, a surface **38**_s_ on the second direction D**2** side of the tip **38** of the first ground electrode **30** is a planar surface perpendicular to the central axis CL. These surfaces **28**_s_**1** and **38**_s_ form the first gap g**1**. In the first gap g**1**, a size dg**1** (also referred to as the "first gap size dg**1**"), that is, the distance between the two surfaces **28**_s_**1** and **38**_s_ is approximately constant irrespective of the position in the first gap g**1**. During manufacturing of the spark plug **100**, the degree of bending of the first ground electrode **30** is adjusted such that the first gap size dg**1** becomes a predetermined size.

As described above, the first ground electrode **30** has the tip **38** formed of the noble metal alloy (specifically, the alloy containing iridium) in the position forming the first gap g**1**. The second ground electrode **90** has the cylindrical tip **98** formed of the noble metal alloy (specifically, the alloy containing iridium) in the position forming the second gap g**2**. In the center electrode **20**, at least the portion forming the first gap g**1** with the tip **38** (that is, the front end surface **28**_s_**1** of the tip **28**) and the portion forming the second gap g**2** with the cylindrical tip **98** (that is, the outer peripheral surface **28**_s_**2** of the tip **28**) are formed of noble metal alloys (specifically, alloys containing iridium). Accordingly, this allows suppressing the wear of each of the center electrode **20**, the first ground electrode **30**, and the second ground electrode **90**.

A3. First Evaluation Test

The following describes the first evaluation test using samples of the spark plug. In the first evaluation test, the relationship between: the ratio of the first gap size dg**1** to the second gap size dg**2**, and the bias eccentricity of the number of discharges between the first gap g**1** and the second gap g**2** was evaluated. To evaluate this relationship, the first evaluation test employed test samples of the spark plug that includes a center electrode with the tip **28**, a first ground electrode with the tip **38**, and a second ground electrode with the cylindrical tip **98** (not shown). The configurations of the center electrode and the first ground electrode of the test samples are similar to the configurations of the center electrode **20** and the first ground electrode **30** in FIG. **1** and FIG. **2**A to FIG. **2**D. For the second ground electrode, the shape of a supporting portion is not same as the shape of the supporting portion **92** in FIG. **1** and FIG. **2**A to FIG. **2**D. However, the supporting portion for the test samples includes a hole forming portion that allows insertion of the cylindrical tip **98** similarly to the hole forming portion **91** described in FIG. **2**A to FIG. **2**D. The cylindrical tip **98** is sealed to the inner peripheral surface of the hole forming portion. The supporting portion for the test samples is sealed to a front end portion of a metal shell. To appropriately perform the above-described evaluation, the respective three tips **28**, **38**, and **98** for the test samples are the same as the three tips **28**, **38**, and **98** described in FIG. **2**A to FIG. **2**D. The configuration of the sample is otherwise similar to the configuration of the spark plug **100** in FIG. **1**. In the first evaluation test, samples of four spark plugs with mutually different ratios dg**1**/dg**2** (hereinafter referred to as "gap ratios") of the first gap size dg**1** to the second gap size dg**2** (in FIG. **2**A) were used to measure the rate (hereinafter referred to as a "second discharge rate") of the number of discharges that occurred between the center electrode and the second ground electrode to the number (here, 100) of all discharges that occurred in the sample of the spark plug. Here, a discharge occurs between the center electrode and the first ground electrode or between the center electrode and the second ground electrode. Table 1 below shows the measurement result.

TABLE 1

	Gap Ratio (dg1/dg2)			
	0.70	0.80	1.25	1.30
Second Discharge Rate (%)	30	45	55	70

The dimensions in common between the four samples used for the evaluation test are as follows.

1) Outer Diameter of Tip **28** of Center Electrode: 2.2 mm
2) Internal Diameter of Cylindrical Tip **98**: 2.8 mm
3) Second Gap Size dg**2**: 0.3 mm

The four samples are different in the first gap size dg**1** from one another. The bent state of the first ground electrode (for example, a bend radius or similar state) is adjusted so as to adjust the first gap size dg**1**.

The testing method is as follows. The sample of the spark plug is arranged in a container for experiment filled with air. The internal pressure of the container is raised to 1 MPa. This pressure is determined assuming the pressure during ignition in the combustion chamber of the internal combustion engine. In this state, a voltage is applied to the sample of the spark plug to conduct a discharge. Every time a discharge is conducted, it is confirmed that the ground electrode that has caused a discharge is the first ground electrode or the second ground electrode by visual check. Hereinafter, the ground electrode that has caused the discharge is referred to as a "discharge ground electrode." The discharge is repeatedly conducted so as to calculate the second discharge rate, that is, the rate of the number of discharges that have occurred between the center electrode and the second ground electrode to the number of all discharges.

As shown in table 1, the second discharge rate becomes higher as the gap ratio becomes larger. As the reason for this result, it is estimated that this is because a discharge is less likely to occur in the first gap g**1** in the case where the gap ratio is large since the first gap size dg**1** is larger than the second gap size dg**2** compared with the case where the gap ratio is small. Specifically, as shown in Table 1, in the case where the gap ratio is 0.70, the second discharge rate is 30%. That is, the discharge ground electrode is biased to the first ground electrode. In the case where the gap ratio is 1.30, the second discharge rate is 70%. That is, the discharge ground electrode is biased to the second ground electrode. In the case where the gap ratio is 0.80, the second discharge rate is 45%. In the case where the gap ratio is 1.25, the second discharge rate is 55%. In these two cases, discharge occurs approximately equally between the first ground electrode and the second ground electrode.

Setting the gap ratio within the range of 0.80 or more and 1.25 or less allows approximately equally using both the first ground electrode and the second ground electrode for discharge. This consequently allows suppressing significant wear of one ground electrode compared with the other ground electrode, thus improving the durability of the spark plug. For example, stable discharges can be achieved over a long period of time.

Here, the test sample has the three tips **28**, **38**, and **98** that form the first gap g**1** and the second gap g**2** similarly to the spark plug **100** shown in FIGS. **2**A to **2**D. Accordingly, the above-described preferred range of the gap ratio is applicable to the spark plug **100** in FIGS. **2**A to **2**D, and thus spark plugs in various configurations with the three tips **28**, **38**, and **98**.

Here, the distance between the two discharging surfaces (here, the outer peripheral surface **28***s***2** of the tip **28** and the inner peripheral surface **98***s* of the cylindrical tip **98**) that form the second gap g**2** might change corresponding to the position on the discharging surface. For example, the displacement (particularly, the displacement in the direction perpendicular to the central axis CL) of the center electrode **20** might be larger than zero. Alternatively, the displacement of the second ground electrode **90** might be larger than zero. In the case where this displacement occurs, the distance between the two discharging surfaces **28***s***2** and **98***s* might change corresponding to the position on the discharging surface **28***s***2**. In this case, it is only necessary to adopt the shortest distance between the two discharging surfaces (here, the two discharging surfaces **28***s***2** and **98***s*) that form the second gap g**2** as the second gap size dg**2**. Similarly, the distance between the two discharging surfaces (here, the front end surface **28***s***1** of the tip **28** and the surface **38***s* of the tip **38**) that form the first gap g**1** might change corresponding to the position on the discharging surface. In this case, it is only necessary to adopt the shortest distance between the two discharging surfaces (here, the two discharging surfaces **28***s***1** and **38***s*) that form the first gap g**1** as the first gap size dg**1**. The first gap size dg**1** and the second gap size dg**2** thus obtained are used to calculate a gap ratio (dg**1**/dg**2**). This gap ratio (dg**1**/dg**2**) is preferred to be within the range of 0.80 or more and 1.25 or less. This allows approximately equally using both the first ground electrode **30** and the second ground electrode **90** for discharge.

Here, the difference in likelihood of discharge between the first gap g**1** and the second gap g**2** is estimated to be caused mainly by the difference between the first gap size dg**1** and the second gap size dg**2**. Accordingly, the above-described preferred range of the gap ratio is estimated to be applicable irrespective of the configuration other than the gap sizes dg**1** and dg**2**. For example, the above-described preferred range is estimated to be applicable irrespective of the material (here, the material of the tip **28** and the material of the tip **38**) of the portion that forms the first gap g**1** in the electrode, the material (here, the material of the tip **28** and the material of the cylindrical tip **98**) of the portion that forms the second gap g**2** in the electrode, and the area of the portions that form the gaps g**1** and g**2** on the surfaces of the electrodes **20**, **30**, and **90**.

A4. Second Evaluation Test

The following describes the second evaluation test using samples of the spark plug. In the second evaluation test, the rate of occurrence of a creeping discharge in the spark plug (referred to as a "used spark plug") after the operation of the internal combustion engine mounted with the sample of the spark plug for 1000 hours was measured.

FIGS. **3**A and **3**B are explanatory views of creeping discharges. The following describes the creeping discharge using the spark plug **100** shown in FIG. **1** and FIGS. **2**A to **2**D. The drawings show the expansion figures of the portions including the gaps g**1** and g**2** in the sectional views shown in FIG. **1** and FIG. **2**B. FIG. **3**A shows a schematic diagram of the spark plug **100** before being used. FIG. **3**B shows a schematic diagram of the spark plug **100** (the spark plug **100** after the operation for 1000 hours) after being used. In FIG. **3**A, bold lines p**1** and p**2** show examples of discharge paths. The first discharge path p**1** is an exemplary path of a discharge that might occur in the first gap g**1**, and is a path from the front end surface **28***s***1** of the tip **28** to the surface **38***s* of the tip **38**. The second discharge path p**2** is an exemplary path of a discharge that occurs in the second gap g**2**, and is a path from the outer peripheral surface **28***s***2** of the tip **28** to the inner peripheral surface **98***s* of the cylindrical tip **98**.

FIG. **3**A shows a distance h that denotes the shortest distance between the surface of the ceramic insulator **10** and the surface of the second ground electrode **90**. In this embodiment, the shortest distance h is the same as the distance (the distance measured in parallel to the central axis CL) between a surface **10***s* (referred to as the "front end surface **10***s*") on the first direction D**1** side of the ceramic insulator **10** and a surface **92***us* on the second direction D**2** side of the supporting portion **92** in the second ground electrode **90**. Before the spark plug **100** is used, the shortest distance h>the first gap size dg**1** is satisfied and the shortest distance h>the second gap size dg**2** is satisfied. The first gap size dg**1** is the same as the second gap size dg**2**.

The electrodes **20**, **30**, and **90** might wear by the operation for 1000 hours. Particularly, wear is likely to occur in the portion that causes a discharge, that is, the front end surface **28***s***1** of the tip **28**, the outer peripheral surface **28***s***2** of the tip **28**, the surface **38***s* of the tip **38**, and the inner peripheral surface **98***s* of the tip **98**. FIG. **3**B shows a schematic diagram after use for 1000 hours. In the drawing, respective surfaces **28***s***1***e*, **28***s***2***e*, **38***se*, and **98***se* are surfaces obtained by wear of the respective original surfaces **28***s***1**, **28***s***2**, **38***s*, and **98***s*. In the first gap g**1** after use, a first gap size dg**1***e* is larger than the first gap size dg**1** before use (in FIG. **3**A). In the second gap g**2** after use, a second gap size dg**2***e* is larger than the second gap size dg**2** before use. Hereinafter, the first gap size dg**1** before use is also referred to as the "first initial gap size dg**1**." The second gap size dg**2** before use is also referred to as a "second initial gap size dg**2**." Here, the electrode wear might progress non-uniformly. In this case, the shortest distance between the front end surface **28***s***1***e* and the surface **38***se* corresponds to the first gap size dg**1***e* after use. The shortest distance between the outer peripheral surface **28***s***2***e* and the inner peripheral surface **98***se* corresponds to the second gap size dg**2***e* after use.

In FIG. **3**B, a bold line px denotes an exemplary path of a creeping discharge. This creeping discharge path px goes from the surface **92***us* of the supporting portion **92** of the second ground electrode **90** to the front end surface **10***s* of the ceramic insulator **10**, goes toward the center electrode **20** along this front end surface **10***s*, and reaches the outer peripheral surface of the center electrode **20** (here, the outer peripheral surface of the electrode base material **21**). The creeping discharge that creeps on the front end surface **10***s* of the ceramic insulator **10** in this method might occur in the case where the discharges in the gaps g**1** and g**2** are less likely to occur. For example, as the gap sizes dg**1***e* and dg**2***e* are larger with respect to the shortest distance h, in other words, as the shortest distance h is smaller with respect to the gap sizes dg**1***e* and dg**2***e*, the creeping discharge is more likely to occur.

When this creeping discharge occurs, the ceramic insulator **10** might be damaged. Accordingly, the rate of occurrence of an unintended creeping discharge is preferred to be small.

The creeping discharge that might occur in the spark plug **100** in FIGS. **2**A to **2**D has been described above. The sample of the spark plug used in the second evaluation test is the same as the sample used for the first evaluation test. The supporting portion of the sample includes the surface **92***us*, which realizes the shortest distance h between the surface of the ceramic insulator **10** and the surface of the second ground electrode, similarly to the supporting portion **92** in FIG. **3**A and FIG. **3**B. Accordingly, in the test sample, in the case where the tips **28**, **38**, and **98** wear due to discharge, the creeping discharge might occur similarly to the spark plug **100** shown in FIG. **3**B.

In the second evaluation test, samples of four spark plugs with different shortest distances h were used to measure the rate of occurrence of the creeping discharge after the operation for 1000 hours. Table 2 below shows the measurement result.

TABLE 2

	Initial Distance Ratio (h/dg)			
	1.8	1.9	2.0	2.1
Occurrence Rate of Creeping Discharge after Use for 1000 Hours	30	10	0	0

In Table 2, an initial distance ratio (h/dg) is the ratio of the shortest distance h to the initial gap sizes dg**1** and dg**2** of the sample of the spark plug before use. The occurrence rate of the creeping discharge after use for 1000 hours is the rate of the number of creeping discharges with respect to the number of all discharges in the case where the sample of the spark plug after use for 1000 hours is used and discharge is repeated under the same condition as that of the first evaluation test. Whether or not the discharge was the creeping discharge was confirmed by visual check.

The dimensions in common between the four samples used for the evaluation test are as follows.

1) Outer Shape of Tip **28** of Center Electrode: 2.2 mm
2) Internal Diameter of Cylindrical Tip **98**: 2.8 mm
3) First Initial Gap Size dg**1**: 0.3 mm
4) Second Initial Gap Size dg**2**: 0.3 mm

The four samples are different in the shortest distance h from one another. The length along the central axis CL of the nose portion **13** of the ceramic insulator **10** is adjusted so as to adjust the shortest distance h.

As shown in Table 2, as the initial distance ratio becomes larger, the rate of the creeping discharge becomes smaller. The reason for this result is estimated as follows. As described above, the gap sizes dg**1***e* and dg**2***e* might become larger than the initial gap sizes dg**1** and dg**2** due to the operation for 1000 hours. Here, in the case where the initial distance ratio is large, the proportion of the gap sizes dg**1***e* and dg**2***e* after use to the shortest distance h is small compared with the case where the initial distance ratio is small. That is, in the case where the initial distance ratio is large, the discharge is likely to occur in the gaps g**1** and g**2** compared with the case where the initial distance ratio is small. Accordingly, in the case where the operating period is the same, that is, in the case where the electrode wear occurs approximately equally, the rate of the creeping discharge becomes smaller as the initial distance ratio becomes larger.

Specifically, as shown in Table 2, in the case where the initial distance ratio is equal to or more than 2.0, more specifically, in the case where the initial distance ratio is 2.0 or 2.1, the occurrence rate of the creeping discharge is zero percent. In the case where the initial distance ratio is 1.9, the occurrence rate of the creeping discharge is 10%. In the case where the initial distance ratio is 1.8, the occurrence rate of the creeping discharge is 30%. Setting the initial distance ratio to be equal to or more than 2 in this method allows suppressing the creeping discharge. This consequently allows improving the durability of the spark plug.

Here, the first initial gap size dg**1** may be different from the second initial gap size dg**2**. In this case, the shortest distance h is preferred to be twice or more as large as the maximum value among the first initial gap size dg**1** and the second initial gap size dg**2**. This configuration allows suppressing the creeping discharge even in the case where any of the first ground electrode **30** and the second ground electrode **90** wears.

In each case, various values can be adopted as the upper limit of the initial distance ratio. For example, the initial distance ratio may be set to be equal to or less than "2.1" that is the evaluated value in the second evaluation test. As the upper limit of the initial distance ratio, the value larger than 2.1 (for example, any value selected from 3, 3.5, and 4) may be adopted (the initial distance ratio is equal to or less than the upper limit). In the case where the first initial gap size dg**1** is different from the second initial gap size dg**2**, the ratio of the shortest distance h to the maximum value between the first initial gap size dg**1** and the second initial gap size dg**2** can be adopted as the initial distance ratio. Here, in the case where the shortest distance h is large, the portion (referred to as the outside portion) positioned on the outside of the through hole **12** of the ceramic insulator **10** in the center electrode **20** is often large. In the case where the outside portion of the center electrode **20** is long, the durability of the center electrode **20** is likely to be low. Accordingly, the shortest distance h, and thus the initial distance ratio is preferred to be small.

As described above, in the test sample, in the case where the tips **28**, **38**, and **98** wear due to discharge, the creeping discharge might occur similarly to the spark plug **100** shown in FIG. **3**B. Accordingly, the above-described preferred range of the initial distance ratio is applicable to the spark plug **100** in FIGS. **2**A to **2**D, and thus spark plugs in various configurations with the three tips **28**, **38**, and **98** and the supporting portion that realizes the shortest distance h.

Here, the rate of electrode wear (for example, an increased amount of the gap sizes dg**1** and dg**2** per unit of operating period) might change corresponding to the materials of the tips **28**, **38**, and **98**, the presence of the tips **28**, **38**, and **98**, the area of the portions that form the gaps g**1** and g**2** on the surfaces of the electrodes **20**, **30**, and **90**, and similar parameter. In each case, when the shortest distance h is twice or more as large as the maximum value among the first initial gap size dg**1** and the second initial gap size dg**2**, the shortest distance h larger than the gap sizes dg**1** and dg**2** can be maintained until the gap sizes dg**1** and dg**2** increases double. This allows suppressing the creeping discharge over a long period of time compared with the case where the shortest distance h is less than twice as large as the above-described maximum value. In this method, the durability of the spark plug can be improved. However, the shortest distance h may be less than twice as large as the maximum value between the first initial gap size dg**1** and the second initial gap size dg**2**.

Here, in the embodiment in FIGS. **3**A and **3**B, the shortest distance h is the distance measured in parallel to the first direction D**1**. The arrangement of the point on the ceramic insulator and the point on the second ground electrode to specify the shortest distance h can be various arrangements corresponding to the shape of the ceramic insulator **10** and the shape of the second ground electrode. For example, the distance measured along the oblique direction intersecting with the first direction D**1** between the ceramic insulator and the second ground electrode may be the shortest distance.

B. Second Embodiment

FIGS. **4**A to **4**D are schematic diagrams showing a second embodiment of the spark plug. FIG. **4**A shows a sectional view similar to that of FIG. **2**A. FIG. **4**B shows a sectional view similar to that of FIG. **2**B. FIG. **4**C shows a schematic diagram similar to that of FIG. **2**C. FIG. **4**D shows a schematic diagram similar to that of FIG. **2**D. There are two differences from the spark plug **100** of the first embodiment. The first difference is that the base material **32** of the first ground electrode **30** of the first embodiment is replaced by a surface layer **36**, which forms the surface, and a core portion **37**, which is formed inside of the surface layer **36**. The second difference is that the supporting portion **92** of the first embodiment is replaced by a surface layer **96**, which forms the surface, and a core portion **97**, which is formed inside of the surface layer **96**. The other configuration of a spark plug **100***a* of the second embodiment is the same as the configuration of the spark plug **100** of the first embodiment (in the drawings, like reference signs designate corresponding or identical configurations, and therefore such configurations will not be further elaborated here). For example, the arrangement of the tips **28**, **38**, and **98** forming the gaps g**1** and g**2** is the same as the arrangement in the embodiment shown in FIGS. **2**A to **2**D. Here, in FIG. **4**C, the core portion **37** is hatched. In FIG. **4**D, the core portion **97** is hatched.

In the second embodiment, a first ground electrode **30***a* includes the surface layer **36**, the core portion **37**, which is disposed inside of the surface layer **36**, and the tip **38**, which is sealed to a front end portion **31***a* of the first ground electrode **30***a*. The outer shape of the surface layer **36** is the same as the outer shape of the base material **32** of the first embodiment. As shown in FIG. **4**A, the core portion **37** extends from the sealed portion with the metal shell **50** and extends to the middle of the first ground electrode **30***a* that reaches the front end portion **31***a*. The front end portion **31***a* is the portion corresponding to the front end portion **31** (in FIG. **2**A) of the first embodiment.

The core portion **37** is formed using a material with a higher thermal conductivity than that of the surface layer **36**. Accordingly, the heat transfer by the first ground electrode **30***a* can be promoted compared with the case where the core portion **37** is omitted. As a result, this simply allows transferring heat from the first ground electrode **30***a* to the metal shell **50** during the operation of the internal combustion engine. Accordingly, this allows suppressing the state where the temperature of the first ground electrode **30***a* becomes high and the long-continued state where the temperature of the first ground electrode **30***a* is high. As a result, this allows suppressing the wear of the first ground electrode **30***a* (for example, oxidation of the surface of the first ground electrode **30***a*).

Here, as the material of the surface layer **36**, various materials can be adopted. For example, an alloy containing nickel can be adopted similarly to the base material **32** of the first embodiment. As the material of the core portion **37**, various materials with higher thermal conductivities than that of the surface layer **36** can be adopted. For example, copper or an alloy containing copper can be adopted.

In the second embodiment, a second ground electrode **90***a* includes the surface layer **96**, the core portion **97**, which is disposed inside of the surface layer **96**, and the cylindrical tip **98**, which is sealed to the inner peripheral surface of the surface layer **96**. The outer shape of the surface layer **96** is the same as the outer shape of the supporting portion **92** of the first embodiment. Hereinafter, the whole of the surface layer **96** and the core portion **97** is referred to as a "supporting portion **92***a*." Reference sign obtained by adding the character "a" to the tail end of reference sign of the element corresponding to the supporting portion **92** in FIGS. **2**A to **2**D is given to the element of the supporting portion **92***a*. For example, a first connecting portion **92***sa* denotes the same portion as the first connecting portion **92***s* in FIG. **2**D. Additionally, an end portion **921***a* denotes the same portion as the end portion **921** in FIG. **2**B. As shown in FIG. **4**B and FIG. **4**D, the core portion **97** extends from the proximity of the end on the −Dy direction side of the supporting portion **92***a* to the proximity of the end on the +Dy direction side within the supporting portion **92***a* along the Y direction Dy. Additionally, the core portion **97** is formed in a ring shape to bypass the through hole and a hole forming portion **91***a*.

The core portion **97** is formed using the material with the higher thermal conductivity than that of the surface layer **96**. Accordingly, the heat transfer by the second ground electrode **90***a* can be promoted compared with the case where the core portion **97** is omitted. As a result, this simply allows transferring heat from the second ground electrode **90***a* to the metal shell **50** during the operation of the internal combustion engine. Accordingly, this allows suppressing the state where the temperature of the second ground electrode **90***a* becomes high and the long-continued state where the temperature of the second ground electrode **90***a* is high. As a result, this allows suppressing the wear of the second ground electrode **90***a* (for example, oxidation of the surface of the second ground electrode **90***a*).

Here, as the material of the surface layer **96**, various materials can be adopted. For example, an alloy containing nickel can be adopted similarly to the supporting portion **92** of the first embodiment. As the material of the core portion **97**, various materials with higher thermal conductivities than that of the surface layer **96** can be adopted. For example, copper or an alloy containing copper can be adopted.

The configuration of the portion other than the above-described two differences of the spark plug **100***a* of the second embodiment is the same as the configuration of the spark plug **100** of the first embodiment. Accordingly, the spark plug **100***a* of the second embodiment can achieve the same advantage as that of the spark plug **100** of the first embodiment. For example, the proportion of the first gap size dg**1** to the second gap size dg**2** is set to be equal to or more than 0.80 and equal to or less than 1.25. This allows approximately equally using both the first ground electrode **30***a* and the second ground electrode **90***a* for discharge. This consequently allows suppressing significant wear of one ground electrode compared with the other ground electrode, thus improving the durability of the spark plug **100***a*. Additionally, similarly to the first embodiment described in FIGS. **3**A and **3**B, setting the shortest distance h to be twice or more as large as the maximum value between the first initial gap size dg**1** and the second initial gap size dg**2** allows suppressing the creeping discharge. As a result, the durability of the spark plug **100** can be improved. Additionally, the first gap g**1** is formed by the noble metal alloy (specifically, the tip **28** and the tip **38**). This allows suppressing the wear of each of the center electrode **20** and the first ground electrode **30***a*. Additionally, the second gap g**2** is formed by the noble metal alloy (specifically, the tip **28** and the cylindrical tip **98**). This allows suppressing the wear of each of the center electrode **20** and the second ground electrode **90***a*. Additionally, as the noble metal, iridium is used. This allows appropriately suppressing the wear of the electrodes **20**, **30***a*, and **90***a*.

C. Third Embodiment

FIGS. **5**A to **5**D are schematic diagrams showing a third embodiment of the spark plug. FIG. **5**A shows a sectional view similar to that of FIG. **4**A. FIG. **5**B shows a sectional view similar to that of FIG. **4**B. FIG. **5**C shows a schematic diagram similar to that of FIG. **4**C. FIG. **5**D shows a schematic diagram similar to that of FIG. **4**D. There are three differences from the spark plug **100***a* of the second embodiment as follows.

1) The first difference is that the large internal diameter portion **501** of the metal shell **50** is omitted.

2) The second difference is that a supporting portion **92***b* (here, a surface layer **96***b*) of a second ground electrode **90***b* extends toward the outside in the radial direction up to the position of the outer peripheral surface of a front end portion **501***b* of a metal shell **50***b*.

3) The third difference is that a first ground electrode **30***b* is sealed to a surface **92***bs* on the first direction D**1** side of the supporting portion **92***b* of the second ground electrode **90***b*. As shown in FIG. **5**B and FIG. **5**C, in the case of the observation facing the direction in parallel to the central axis CL, the direction in which the first ground electrode **30***b* extends from the sealed portion with the metal shell **50***b* toward the central axis CL is parallel to the direction (here, the Y direction Dy) in which the second ground electrode **90***b* extends.

The other configuration of a spark plug **100***b* of the third embodiment is the same as the configuration of the spark plug **100***a* of the second embodiment (in the drawings, like reference signs designate corresponding or identical configurations, and therefore such configurations will not be further elaborated here). For example, the configuration of the metal shell **50***b* of the third embodiment is the same as the configurations of the metal shells **50** of the first and second embodiments except that the portion that forms the large internal diameter portion **501** is omitted. The arrangement of the tips **28**, **38**, and **98** forming the gaps g**1** and g**2** is the same as the arrangements in the embodiments shown in FIGS. **2**A to **2**D and FIGS. **4**A to **4**D.

As shown in FIG. **5**B and FIG. **5**D, the second ground electrode **90***b* includes the supporting portion **92***b* and the cylindrical tip **98**. The supporting portion **92***b* includes the hole forming portion **91***a* same as that of the embodiment of FIG. **4**B. The cylindrical tip **98** is sealed to the inner peripheral surface of this hole forming portion **91***a*. As shown in FIG. **5**B and FIG. **5**D, the core portion **97** is disposed inside of the supporting portion **92***b* similarly to the embodiment in FIG. **4**B and FIG. **4**D. The remaining portion other than the core portion **97** in the supporting portion **92***b* is the surface layer **96***b*. The surface layer **96***b* is formed using a nickel alloy.

As shown in FIG. **5**B, an end portion **921***b* of the supporting portion **92***b* is the end portion **921***b* on the outside in the radial direction and on the second direction D**2** side. In this end portion **921***b*, an end face **92***s***2** on the second direction D**2** side is sealed to the end face (referred to as a "front end surface **501***sb*") on the first direction D**1** side of the metal shell **50***b*. For example, a boundary portion W**95***b* between the supporting portion **92***b* and the metal shell **50***b* is welded by laser beam welding from outside in the radial direction. These surfaces **92***s***2** and **501***sb* are each a planar surface perpendicular to the central axis CL. FIG. **5**B and FIG. **5**D show two connecting portions **92***sb* and **92***tb*. The first connecting portion **92***sb* is the portion on the −Dy direction side with respect to the central axis CL in the supporting portion **92***b*. The second connecting portion **92***tb* is the portion on the +Dy direction side with respect to the central axis CL in the supporting portion **92***b*. The end portion **921***b* of the first connecting portion **92***sb* is sealed to the metal shell **50***b* on the −Dy direction side with respect to the central axis CL. The end portion **921***b* of the second connecting portion **92***tb* is sealed to the metal shell **50***b* on the +Dy direction side with respect to the central axis CL.

In this embodiment, as shown in FIG. **5**D, the shapes of edges **92***so* on the outer periphery side of the two end faces **92***s***2** in the supporting portion **92***b* are the same as a part of the circle (that is, the arc) having approximately the same diameter as the outer diameter of the front end surface **501***sb* of the metal shell **50***b*. As shown in FIG. **5**D, the shapes of edges **92***si* on the inner peripheral side of the two end faces **92***s***2** in the supporting portion **92***b* are the same as a part of the circle (that is, the arc) having a slightly smaller diameter than the internal diameter of the front end surface **501***sb* of the metal shell **50***b*. Accordingly, the front end surface **501***sb* of the metal shell **50***b* can be simply sealed to the two end faces **92***s***2** of the supporting portion **92***b*. This allows enhancing the sealing strength. Additionally, the edges **92***so* on the outer periphery side of the two end faces **92***s***2** in the supporting portion **92***b* is arranged on the edge on the outer periphery side of the front end surface **501***sb* of the metal shell **50***b*. This allows suppressing the displacement (the displacement in the direction perpendicular to the central axis CL) of the second ground electrode **90***b* with respect to the metal shell **50***b*. As a result, the second gap size dg**2** is approximately constant over the whole circumference on the outer peripheral surface **28***s***2** of the tip **28** of the center electrode **20**.

As shown in FIG. **5**B, the first ground electrode **30***b* is sealed to the surface **92***bs* on the first direction D**1** side of the supporting portion **92***b* of the second ground electrode **90***b* (for example, by laser beam welding). The configuration of the first ground electrode **30***b* is the same as the configuration obtained by omitting the portion overlapping with the second ground electrode **90***b* in FIG. **5**B in the first ground electrode **30***a* in the case where the first ground electrode **30***a* in FIG. **4**A is superimposed on FIG. **5**B such that the tips **38** overlap with each other. Similarly to the first ground electrode **30***a* in FIG. **4**A, the first ground electrode **30***b* includes a surface layer **36***b*, a core portion **37***b*, which is formed inside of the surface layer **36***b*, and the tip **38**.

The first ground electrode **30***b* is sealed to the metal shell **50***b* via the second ground electrode **90***b*. In this case, the heat transfer from the first ground electrode **30***b* to the metal shell **50***b* is suppressed compared with the case where the first ground electrode **30***b* is sealed directly to the metal shell **50***b*. Accordingly, the temperature of the first ground electrode **30***b* is likely to increase. However, the core portion **37***b* is buried in the first ground electrode **30***b*. Accordingly, this allows suppressing the state where the temperature of the first ground electrode **30***b* becomes high and the long-continued state where the temperature of the first ground electrode **30***b* is high. As a result, this allows suppressing the wear of the first ground electrode **30***b* (for example, oxidation of the surface of the first ground electrode **30***b*).

The configuration of the portion other than the above-described differences of the spark plug **100***b* of the third embodiment is the same as the configuration of the spark plug **100***a* of the second embodiment. Accordingly, the spark plug **100***b* of the third embodiment can achieve the same advantage as that of the spark plug **100***a* of the second embodiment. For example, the proportion of the first gap size dg**1** to the second gap size dg**2** is set to be equal to or more than 0.80 and equal to or less than 1.25. This allows approximately equally using both the first ground electrode **30***b* and the second ground electrode **90***b* for discharge. This consequently allows suppressing significant wear of one ground electrode compared with the other ground electrode, thus improving the durability of the spark plug **100***b*. Similarly to the first embodiment described in FIGS. **3**A and **3**B, setting the shortest distance h to be twice or more as large as the maximum value between the first initial gap size dg**1** and the second initial gap size dg**2** allows suppressing the creeping discharge. As a result, the durability of the spark plug **100***b* can be improved. Additionally, the first gap g**1** is formed by the noble metal alloy (specifically, the tip **28** and the tip **38**). This allows suppressing the wear of each of the center electrode **20** and the first ground electrode **30***b*. Additionally, the second gap g**2** is formed by the noble metal alloy (specifically, the tip **28** and the cylindrical tip **98**). This allows suppressing the wear of each of the center electrode **20** and the second ground electrode **90***b*. Additionally, as the noble metal, iridium is used. This allows appropriately suppressing the wear of the electrodes **20**, **30***b*, and **90***b*. Additionally, the core portion **37***b* with the higher thermal conductivity than that of the surface layer **36***b* is buried inside of the first ground electrode **30***b*. Accordingly, this allows suppressing the state where the temperature of the first ground electrode **30***b* becomes high and the long-continued state where the temperature of the first ground electrode **30***b* is high during the operation of the internal combustion engine. As a result, this allows suppressing the wear of the first ground electrode **30***b* (for example, oxidation of the surface of the first ground electrode **30***b*). Additionally, the core portion **97** with the higher thermal conductivity than that of the surface layer **96***b* is buried inside of the second ground electrode **90***b*. Accordingly, this allows suppressing the state where the temperature of the second ground electrode **90***b* becomes high and the long-continued state where the temperature of the second ground electrode **90***b* is high during the operation of the internal combustion engine. As a result, this allows suppressing the wear of the second ground electrode **90***b* (for example, oxidation of the surface of the second ground electrode **90***b*).

D. Fourth Embodiment

FIGS. **6**A to **6**D are schematic diagrams showing a fourth embodiment of the spark plug. FIG. **6**A shows a sectional view similar to that of FIG. **5**A. FIG. **6**B shows a sectional view similar to that of FIG. **5**B. FIG. **6**C shows a schematic diagram similar to that of FIG. **5**C. FIG. **6**D shows a schematic diagram similar to that of FIG. **5**D. There is a difference from the spark plug **100***b* of the third embodiment only in that the sealed surface between a metal shell **50***c* and a supporting portion **92***c* changes in a stepped shape. The other configuration of a spark plug **100***c* is the same as the configuration of the spark plug **100***b* of the third embodiment (in the drawings, like reference signs designate corresponding or identical configurations, and therefore such configurations will not be further elaborated here). For example, the configuration of the metal shell **50***c* of the fourth embodiment is the same as the configurations of the metal shells **50** of the first and second embodiments except that the shape of a front end portion **501***c* is different. Additionally, the configuration of a second ground electrode **90***c* of the fourth embodiment is the same as the configuration of the second ground electrode **90***b* in FIG. **5**A except that the shape (the shape of the portion to be sealed to the metal shell **50***c*) of an end portion **921***c* of the supporting portion **92***c* is different from the shape (the shape of the portion to be sealed to the metal shell **50***b*) of the end portion **921***b* of the supporting portion **92***b* in FIG. **5**B. The arrangement of the tips **28**, **38**, and **98** that form the gaps g**1** and g**2** is the same as the arrangement of the embodiments in FIGS. **2**A to **2**D, FIGS. **4**A to **4**D, and FIGS. **5**A to **5**D. Here, the right side of FIG. **6**B shows an expansion figure of the sealed portion between the metal shell **50***c* and the second ground electrode **90***c*.

As shown in FIG. **6**B and FIG. **6**D, the second ground electrode **90***c* includes the supporting portion **92***c* and the cylindrical tip **98**. The configuration other than the shape of the sealed surface with the metal shell **50***c* in the configuration of the supporting portion **92***c* is the same as the configuration of the supporting portion **92***b* in FIG. **5**B and FIG. **5**D. The cylindrical tip **98** is sealed to the inner peripheral surface of the hole forming portion **91***a* of the supporting portion **92***c*. The same core portion **97** as that of the third embodiment is disposed inside of the supporting portion **92***c*. The remaining portion other than the core portion **97** in the supporting portion **92***c* is a surface layer **96***c*. In the drawings, a first connecting portion **92***sc* is the portion on the −Dy direction side with respect to the central axis CL in the supporting portion **92***c*, and a second connecting portion **92***tc* is the portion on the +Dy direction side with respect to the central axis CL in the supporting portion **92***c*. As shown in FIG. **6**B, the end portion **921***c* of the first connecting portion **92***sc* is sealed to the metal shell **50***c* on the −Dy direction side with respect to the central axis CL. The end portion **921***c* of the second connecting portion **92***tc* is sealed to the metal shell **50***c* on the +Dy direction side with respect to the central axis CL.

As shown in the expansion figure in FIG. **6**B, the end portion **921***c* of the supporting portion **92***c* includes an inside portion **941***d*, which is the portion on the inner peripheral side, and an outside portion **941***e*, which is the portion on the outside in the radial direction of the inside portion **941***d*. As shown in FIG. **6**B, a surface **941***ds* on the second direction D**2** side of the inside portion **941***d* and a surface **941***es* on the second direction D**2** side of the outside portion **941***e* are both planar surfaces perpendicular to the central axis CL. However, the surface **941***es* of the outside portion **941***e* is positioned on the first direction D**1** side with respect to the surface **941***ds* of the inside portion **941***d*. In the boundary portion between the inside portion **941***d* and the outside portion **941***e*, an outer peripheral surface **941***fs* (also referred to as the partial cylindrical surface **941***fs*) is formed. The outer peripheral surface **941***fs* has the same shape as that of a part of a cylinder having the center on the central axis CL.

As shown in FIG. **6**B, the front end portion **501***c* of the metal shell **50***c* includes an inside portion **501***d* and an outside portion **501***e*, which is the portion on the outside in the radial direction of the inside portion **501***d*. A surface **501***ds* on the first direction D**1** side of the inside portion **501***d* and a surface **501***es* on the first direction D**1** side of the outside portion **501***e* are each a planar surface perpendicular to the central axis CL. However, the surface **501***es* of the outside portion **501***e* is positioned on the first direction D**1** side with respect to the surface **501***ds* of the inside portion **501***d*. In the boundary portion between the inside portion **501***d* and the outside portion **501***e*, an inner peripheral surface **501***fs* (also referred to as the partial cylindrical surface **501***fs*) is formed. The inner peripheral surface **501***fs* has the same shape as that of a part of a cylinder having the center on the central axis CL.

As shown in FIG. **6**B, the second ground electrode **90***c* is fitted to the front end portion **501***c* of the metal shell **50***c* from the first direction D**1** side toward the second direction D**2**. The surface **941***es* of the outside portion **941***e* of the supporting portion **92***c* is brought into contact with the surface **501***es* of the outside portion **501***e* of the metal shell **50***c*. The surface **941***ds* of the inside portion **941***d* of the supporting portion **92***c* is brought into contact with the surface **501***ds* of the inside portion **501***d* of the metal shell **50***c*. A boundary portion W**95***c* between the supporting portion **92***c* and the metal shell **50***c* is welded by laser beam welding from outside in the radial direction.

The partial cylindrical surface **941***fs* of the supporting portion **92***c* is brought into contact with the partial cylindrical surface **501***fs* of the metal shell **50***c*. Accordingly, this allows suppressing the displacement (the displacement in the direction perpendicular to the central axis CL) of the second ground electrode **90***c* with respect to the metal shell **50***c*. As a result, the second gap size dg**2** is approximately constant over the whole circumference on the outer peripheral surface of the tip **28** of the center electrode **20**.

As shown in FIG. **6**B, the first ground electrode **30***b* is sealed to the surface **92***bs* on the first direction D**1** side of the supporting portion **92***c* of the second ground electrode **90***c* (for example, by laser beam welding). Here, a depressed portion or a cutout may be disposed on the surface **92***bs* on the first direction D**1** side of the supporting portion **92***c* of the second ground electrode **90***c*, and one end portion of the first ground electrode **30***b* may be arranged to be sealed to the depressed portion or the cutout.

Here, the configuration of the portion other than the above-described difference of the spark plug **100***c* of the fourth embodiment is the same as the configuration of the spark plug **100***b* of the third embodiment. Accordingly, the spark plug **100***c* of the fourth embodiment can achieve various advantages similar to those of the spark plug **100***b* of the third embodiment. For example, the proportion of the first gap size dg**1** to the second gap size dg**2** is set to be equal to or more than 0.80 and equal to or less than 1.25. This allows approximately equally using both the first ground electrode **30***b* and the second ground electrode **90***c* for discharge. This consequently allows suppressing significant wear of one ground electrode compared with the other ground electrode, thus improving the durability of the spark plug **100***c*. Similarly to the first embodiment described in FIGS. **3**A and **3**B, setting the shortest distance to be twice or more as large as the maximum value between the first initial gap size dg**1** and the second initial gap size dg**2** allows suppressing the creeping discharge. As a result, the durability of the spark plug **100***c* can be improved. Additionally, the first gap g**1** is formed by the noble metal alloy (specifically, the tip **28** and the tip **38**). This allows suppressing the wear of each of the center electrode **20** and the first ground electrode **30***b*. Additionally, the second gap g**2** is formed by the noble metal alloy (specifically, the tip **28** and the cylindrical tip **98**). This allows suppressing the wear of each of the center electrode **20** and the second ground electrode **90***c*. Additionally, as the noble metal, iridium is used. This allows appropriately suppressing the wear of the electrodes **20**, **30***b*, and **90***c*. Additionally, the core portion **37***b* with the higher thermal conductivity than that of the surface layer **36***b* is buried inside of the first ground electrode **30***b*. Accordingly, this allows suppressing the wear of the first ground electrode **30***b*. Additionally, the core portion **97** with the higher thermal conductivity than that of the surface layer **96***c* is buried inside of the second ground electrode **90***c*. Accordingly, this allows suppressing the wear of the second ground electrode **90***c*.

E. Modifications

(1) In the above-described respective embodiments, the first ground electrode is preferred to include a first nickel portion that is the portion formed by nickel or a nickel alloy, and the nickel content of the first nickel portion is preferred to be equal to or more than 90 weight %. For example, in the above-described embodiments, the base material **32** in FIG. **2**A and the surface layers **36** and **36***b* in FIG. **4**A, FIG. **5**B, and FIG. **6**B each correspond to the first nickel portion. An increase in nickel content allows improving the thermal conductivity of the first ground electrode. Accordingly, this simply allows transferring heat from the first ground electrode to the metal shell during the operation of the internal combustion engine. Thus, this allows suppressing the state where the temperature of the first ground electrode becomes high and the long-continued state where the temperature of the first ground electrode is high. As a result, this allows suppressing the wear of the first ground electrode (for example, oxidation of the surface of the first ground electrode). However, the nickel content of the first nickel portion of the first ground electrode may be less than 90 weight %.

Similarly, the second ground electrode is preferred to include a second nickel portion that is the portion formed by nickel or a nickel alloy, and the nickel content of the second nickel portion is preferred to be equal to or more than 90 weight %. For example, in the above-described embodiments, the entire supporting portion **92** in FIG. **2**A and the surface layers **96**, **96***b*, and **96***c* in FIG. **4**B, FIG. **5**B, and FIG. **6**B each corresponds to the second nickel portion. In the case where the nickel content of this second nickel portion is equal to or more than 90 weight %, this simply allows transferring heat from the second ground electrode to the metal shell during the operation of the internal combustion engine. Thus, this allows suppressing the state where the temperature of the second ground electrode becomes high and the long-continued state where the temperature of the second ground electrode is high. As a result, this allows suppressing the wear of the second ground electrode (for example, oxidation of the surface of the second ground electrode). However, the nickel content of the second nickel portion of the second ground electrode may be less than 90 weight %.

However, the first ground electrode may be formed using a conductive material other than nickel without containing nickel. Similarly, the second ground electrode may be formed using a conductive material other than nickel without containing nickel.

(2) In the above-described embodiments that include the core portions **37** and **37***b* of the first ground electrodes, the core portions **37** and **37***b* may be omitted. Additionally, in the embodiment without the core portion, the core portion (for example, the core portions **37** and **37***b*) may be added. Additionally, in the embodiment that includes the core portion **97** of the second ground electrode, the core portion **97** may be omitted. In the embodiment without the core portion **97**, the core portion **97** may be added. In this method, the core portion may be disposed only in any one of the first ground electrode and the second ground electrode. The core portion may be omitted from both the first ground electrode and the second ground electrode. The core portion may be disposed in both the first ground electrode and the second ground electrode.

As the material of the core portion, various materials with larger thermal conductivities than that of the surface layer disposed in the peripheral area of the core portion can be adopted. For example, a conductive material such as copper, an alloy containing copper, and silver can be adopted.

(3) In the above-described respective embodiments, respective noble metal tips apart from one another may be disposed in the portion that forms the first gap g**1** and the portion that forms the second gap g**2** in the center electrode **20**. Additionally, the above-described respective embodi-

ments, at least one of the noble metal tips **38** and **98** disposed in the ground electrode may be omitted. In the above-described respective embodiments, the noble metal tips of one or more portions optionally selected from the portion that forms the first gap g**1** of the center electrode **20**, the portion that generates the second gap g**2** of the center electrode **20**, the portion that forms the first gap g**1** of the first ground electrode, and the portion that forms the second gap g**2** of the second ground electrode may be omitted.

The material of the noble metal tip is not limited to iridium or an alloy containing iridium, and other various materials can be adopted. For example, platinum or an alloy containing platinum may be adopted. Generally, a noble metal or a noble metal alloy can be adopted. Additionally, the respective materials of the noble metal tips in the portion that forms the first gap g**1** of the center electrode **20**, the portion that generates the second gap g**2** of the center electrode **20**, the portion that forms the first gap g**1** of the first ground electrode, and the portion that forms the second gap g**2** of the second ground electrode may be selected independently from one another. For example, the tip **28** may be formed using the noble metal (for example, iridium). The noble metal tip **38** and the cylindrical tip **98** may be formed using the noble metal alloy (for example, an iridium alloy).

(4) The area of the discharging surface (in the above-described respective embodiments, the area of the inner peripheral surface **98***s* of the cylindrical tip **98**) that forms the second gap g**2** of the second ground electrode is preferred to be twice or more as large as the area of the discharging surface (in the above-described respective embodiments, the area of the surface **38***s* of the tip **38**) that forms the first gap g**1** of the first ground electrode. This configuration achieves the area of the discharging surface three times as large as the area in the case where the second ground electrode is omitted, thus improving the durability of the spark plug. For example, a stable discharge can be achieved over a long period of time.

(5) To suppress the displacement (particularly, the displacement in the direction intersecting with the central axis CL) of the second ground electrode with respect to the metal shell, the second ground electrode is preferred to be the surface in contact with the metal shell and to have the surface (referred to as a "position specifying surface") specified by the normal line intersecting with the first direction D**1**. For example, in the above-described embodiments, the surfaces on the outside in the radial direction of the two end portions **921** and **921***a* of the supporting portions **92** and **92***a* in FIGS. **2**A to **2**D and FIGS. **4**A to **4**D and the surfaces (the partial cylindrical surface **941***fs*) on the outside in the radial direction of the inside portion **941***d* of the two end portions **921***c* in the supporting portion **92***c* in FIGS. **6**A to **6**D respectively correspond to the position specifying surface. In these embodiments, the normal direction of the position specifying surface is the same as the radial direction in the position specifying surface. Generally, the second ground electrode is preferred to have two or more position specifying surfaces that are arranged in mutually different directions observed from the central axis CL and have mutually different normal directions. This configuration allows appropriately suppressing the displacement (the displacement in the direction intersecting with the central axis CL) of the second ground electrode with respect to the metal shell. For example, the configuration where the depressed portion or the convex portion of the second ground electrode is fitted to the convex portion or the depressed portion of the metal shell can be adopted. Here, the normal direction of the position specifying surface may be the direction obliquely inclined with respect to the planar surface perpendicular to the central axis CL. However, to suppress the displacement in the first direction D**1** of the second ground electrode, the normal direction of the position specifying surface is preferred to be the same as the radial direction in the position specifying surface.

Here, the configurations of the center electrode, the first ground electrode, and the second ground electrode are not limited to the above-described configurations. Other various configurations can be adopted.

The present invention has been described above based on the embodiment and the modifications. The above-described embodiments of the invention are for ease of understanding of the present invention and do not limit the present invention. The present invention may be modified or improved without departing from the gist and the claims of the present invention, and includes the equivalents.

INDUSTRIAL APPLICABILITY

The present invention is preferably applicable to a spark plug that includes a center electrode, a first ground electrode that forms a first gap with a front end surface of the center electrode, and a second ground electrode that forms an annular second gap between the side surface of the center electrode and the inner peripheral surface of the second ground electrode.

DESCRIPTION OF REFERENCE SIGNS

5 Gasket
6 First rear-end-side packing
7 Second rear-end-side packing
8 Front-end-side packing
9 Talc
10 Ceramic insulator
10*s* Front end surface
11 Second outer-diameter contracted portion
12 Through hole
13 Nose portion
15 First outer-diameter contracted portion
17 Front-end-side trunk portion
18 Rear-end-side trunk portion
19 Flange portion
20 Center electrode
21 Electrode base material
22 Core material
28*s***2***e* Outer peripheral surface
28*s***1***e* Front end surface
28 Tip
28*s***1** Front end surface
28*s***2** Outer peripheral surface
30, **30***a*, and **30***b* First ground electrode
31 Front end portion
31*a* Front end portion
32 Base material
36 and **36***b* Surface layer
37 and **37***b* Core portion
38 Tip
38*s* Surface
38*se* Surface
40 Terminal metal fitting
41 Plug cap installation portion
42 Flange portion
43 Nose portion
50 Metal shell
50*b* Metal shell
50*c* Metal shell
51 Tool engagement portion

52 Screw portion
53 Crimp portion
54 Seal portion
55 Body
56 Inner-diameter contracted portion
58 Deformed portion
59 Through hole
60 Conductive seal
70 Resistor element
80 Conductive seal
90, **90***a*, **90***b*, and **90***c* Second ground electrode
91 and **91***a* Hole forming portion
92, **92***a*, **92***b*, and **92***c* Supporting portion
92*s* and **92***sa* to **92***sc* First connecting portion
92*t* and **92***ta* to **92***tc* Second connecting portion
92*s***2** End face
92*so* and **92***si* Edge
92*us* and **92***bs* Surface
96, **96***b*, and **96***c* Surface layer
97 Core portion
98 Cylindrical tip
98*s* Inner peripheral surface
98*se* Inner peripheral surface
100, **100***a*, **100***b*, and **100***c* Spark plug
501 Large internal diameter portion
501*b* and **501***c* Front end portion
501*d* Inside portion
501*e* Outside portion
501*s* and **501***sb* Front end surface
501*ds* and **501***es* Surface
501*fs* Inner peripheral surface (Partial cylindrical surface)
502 Small internal diameter portion
921 and **921***a* to **921***c* End portion
941*d* Inside portion
941*e* Outside portion
941*ds* and **941***es* Surface
941*fs* Outer peripheral surface (partial cylindrical surface)
h Shortest distance
W**95**, W**95***b*, and W**95***c* Boundary portion
g**1** First gap
g**2** Second gap
CL Central axis
dg**1** and dg**1***e* First gap size
dg**2** and dg**2***e* Second gap size

Having described the invention, the following is claimed:

1. A spark plug, comprising:

a center electrode that extends in an axial direction;

an insulator that has an axial hole extending in the axial direction, the center electrode being to be inserted into the axial hole;

a metal shell arranged at an outer periphery of the insulator;

a first ground electrode that has electrical continuity with the metal shell, the first ground electrode forming a first gap with a front end surface of the center electrode; and

a second ground electrode that has electrical continuity with the metal shell, the second ground electrode being sealed to metal shell, the second ground electrode extending from the metal shell to a position facing a side surface of the center electrode, the second ground electrode forming an annular second gap between the side surface of the center electrode and an inner peripheral surface of the second ground electrode, wherein

a proportion of a size of the first gap to a size of the second gap is equal to or more than 0.80 and equal to or less than 1.25.

2. The spark plug according to claim **1**, wherein

the first ground electrode includes a first nickel portion that is a portion formed by nickel or a nickel alloy, the first nickel portion having a nickel content of 90 weight % or more, and

the second ground electrode includes a second nickel portion that is a portion formed by nickel or a nickel alloy, the second nickel portion having a nickel content of 90 weight % or more.

3. The spark plug according to claim **1** or **2**, wherein

at least one of the first ground electrode and the second ground electrode includes: a surface layer that forms a surface thereof; and a core portion that is formed inside of the surface layer and has a larger thermal conductivity than a thermal conductivity of the surface layer.

4. The spark plug according to claim **3**, wherein

the first ground electrode is sealed to the second ground electrode.

5. The spark plug according to claim **1** or **2**, wherein

a shortest distance between a surface of the second ground electrode and a surface of the insulator is twice or more as large as a maximum value among the size of the first gap and the size of the second gap.

6. The spark plug according to claim **1** or **2**, wherein

the first ground electrode includes a first noble metal portion that is formed by a noble metal or a noble metal alloy in a position forming the first gap,

the second ground electrode includes a second noble metal portion that is formed by a noble metal or a noble metal alloy in a position forming the second gap, and

in the center electrode, at least a first portion and a second portion are formed by a noble metal or a noble metal alloy, the first portion forming the first gap with the first noble metal portion, the second portion forming the second gap with the second noble metal portion.

7. The spark plug according to claim **6**, wherein

the noble metal or the noble metal alloy is iridium or an iridium alloy.

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